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HALOCARBON RECOVERY, RECYCLING, AND RECLAMATION: ISSUES, EQUIPMENT, AND SERVICES

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The objective of this project was to identify commercially available equipment and services for recovery of chlorofluorocarbons (CFCs) halons, and related alternative materials. Characteristics of available equipment have been collected and put into tabular form for ease of comparison. Capabilities and specifications for the equipment included in this study have been reported as received from the manufacturers. Concerns and issues related to the recovery/recycling/reclamation (R/R/R) of halocarbons were also identified and discussed.

14. SUBJECT TERMS

Halon, CFC, chlorofluorocarbon, recycling, recovery, reclamation, halocarbon, reuse

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EXECUTIVE SUMMARY

A. OBJECTIVE

The objective of this project was to identify commercially available equipment and services for recovery of chlorofluorocarbons (CFCs), halons, and related alternative materials. The results of the market survey study are documented in this report. This report also includes an evaluation of the available equipment and the issues related to halocarbon recovery, recycling, and reclamation, with recommendations.

B. BACKGROUND

The Montreal Protocol on Substances that Deplete the Ozone Layer, an international treaty under the auspices of the United Nations Environment Programme, was signed by 41 countries in 1987. It is intended to control the production and consumption of CFC-11, -12, -113, -114, and -115 and Halons 1211, 1301, and 2402. These materials are suspected to deplete stratospheric ozone. The review of the Montreal Protocol in June 1990 resulted in accelerated and increased production restrictions.

CFCs are widely used in refrigeration and air-conditioning systems for automobile, home, and commercial applications. In addition, they are used as cleaning solvents, sterilants, aerosols, and foam-blowing agents. Halons are effective, clean firefighting agents in wide use in portable extinguishers and fixed installations. CFCs are released in processes such as chemical production, foam manufacturing, electronic and metal component cleaning, and medical product sterilization. In the past, it has often been accepted practice to vent CFCs and halons to the atmosphere when servicing equipment such as refrigeration units or fire protection systems. Venting was often used because of the relatively low cost of new replacement agents and the unknown impact on stratospheric ozone.

Because of the past industry practice of releasing halocarbons into the atmosphere, equipment for their recovery, recycling, reclamation, and/or reuse was not in demand. The number of companies making recovery/recycling equipment or providing recycling and reclamation services is now rapidly expanding to meet the growing demand.

C. SCOPE

The scope of this effort was to conduct a market survey of all known equipment or services available for recovering/recycling of CFCs, halons, and related materials. The term "halocarbon" is used as a generic term for these halogenated hydrocarbons. The results of this survey include all technical information available about the equipment or service, cost, and availability. An evaluation and rating of equipment categories to perform specific functions is also included. It is based strictly on claims by the equipment manufacturers.

D. METHODOLOGY

Companies known to be involved in halocarbon recovery/recycling were requested to provide information on their products and/or services. The list of 34 companies (32 in the U.S. and 2 in Canada) was developed from an initial list provided by the United States Environmental Protection Agency (EPA), Division of Global Change, Washington, DC, and was augmented through industry publications, literature, and contacts. The data gathered from these companies were reviewed, evaluated, and put in tabular form for ease of comparison.

E. TEST DESCRIPTION

Neither experimental work nor tests were performed for this project.

F. RESULTS

Commercially available equipment and services have been identified in this study for the recovery, recycling, and reclamation (R/R/R) of used halocarbons in the refrigeration, air-conditioning, heat pump, and halon fire protection use sectors. Characteristics of available equipment have been collected and put into tabular form for ease of comparison. Capabilities and specifications for the equipment included in this study have been reported as received from the manufacturers.

G. CONCLUSIONS

Most of the recovery/recycling equipment available is targeted for CFCs in the mobile air-conditioning and stationary refrigeration and air-conditioning equipment market. Very little equipment is presently available specifically for R/R/R of halons. Performance standards have been established for mobile air-conditioning. The equipment certified to meet these standards is identified in Table C-1.

Concerns and issues relevant to the R/R/R of halocarbons were identified and discussed. The key issues are related to identification of acceptable purity and quality assurance requirements of recycled halocarbons. The resolution of these issues will require extensive study and testing throughout the industry.

H. RECOMMENDATIONS

Recovery, recycling, and reclamation requirements for reduction of halocarbon emissions have far reaching implications for all organizations, including the USAF. The traditional procedures involving CFCs as cooling and cleaning fluids and halons as fire extinguishing agents will require significant changes. Decreasing availability and increasing costs of halocarbons dictate development of a R/R/R conservation program in the short term and investment in technologies for selection of alternative chemicals and equipment in the long term.

Purchasers of R/R/R equipment should ensure that the equipment has been tested by an independent party to verify performance for their specific applications.

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PREFACE

This report was prepared by the New Mexico Engineering Research Institute (NMERI), University of New Mexico, Albuquerque, New Mexico 87131, under Subtask 2.16, contract F29601-87-C-0001, for the Engineering and Services Program Office, Air Force Engineering and Services Center, Tyndall Air Force Base, Florida 32403.

The report summarizes work performed for the evaluation CFC and halon recovery, recycle, and reclamation equipment, services, and issues during April and May 1990. The NMERI Principal Investigator was Dr. Robert E. Tapscott. The Project Officer was Mr. Robert W. Rettie, HQ AFESC/YE. This project was coordinated with the AFESC/RD, Engineering Research Division.

This report has been reviewed by the Public Affairs Office (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nationals.

This technical report has been reviewed and is approved for publication.

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SECTION I
INTRODUCTION

A. OBJECTIVE

The objective of this project was to identify commercially available equipment and services for recovery of chlorofluorocarbons (CFCs), halons, and related alternative materials. The results of the market survey study include the following: (1) name, address, and telephone number for vendors; (2) descriptions of the systems and prices; (3) performance data such as discharge and recharge rates, weights, dimensions, and compatible halocarbons; (4) identification of the halocarbon purification systems, what contaminants can be removed, and how purity can be verified; (5) training availability and adequacy of operation and maintenance documentation; and (6) data indicating system maturity and reliability including historical data on the number of systems in use. This report also includes an evaluation of the available equipment (based strictly on claims of the equipment manufacturers) and the issues related to halocarbon recovery, recycling, and reclamation, with recommendations.

B. BACKGROUND

The Montreal Protocol on Substances that Deplete the Ozone Layer, an international treaty under the auspices of the United Nations Environment Programme, was signed by 41 countries in 1987. It is intended to control the production and consumption (defined as production minus exports, plus imports, with adjustments for materials destroyed or produced as intermediates) of CFC-11, -12, -113, -114, and -115 and Halons 1211, 1301, and 2402 (Reference 1). These materials are suspected to deplete stratospheric ozone. The Protocol has now been ratified by 62 countries, including the U.S., and, effective 1 July 1989, restricts production of the listed CFCs to 1986 levels. Further restrictions in production levels to 80 percent of 1986 levels effective 1 July 1993 and 50 percent of 1986 levels effective 1 July 1998 are specified. The Protocol also limits consumption of halons to 1986 levels beginning in 1992, but no further halon restrictions are mandated in the present version. In April 1989, 70 nations met in Helsinki and adopted a nonbinding resolution that calls for a complete phaseout of the controlled CFCs and halons as soon as possible but no later than the year 2000. A review of the Montreal Protocol during June 1990, in London, however, resulted in accelerated and increased production restrictions. Methyl chloroform and carbon tetrachloride were also proposed for regulation due to their suspected depletion of stratospheric ozone, as were several other fully halogenated hydrocarbons. Production of CFCs and noncritical-use halons will almost certainly be phased out by 2000 (Reference 2).

The CFCs and halons are members of the halogenated aliphatic hydrocarbon (halocarbon) family of compounds. CFCs are widely used in refrigeration and air-conditioning systems for automobile, home, and commercial applications. In addition, they are used as cleaning solvents, sterilants, aerosols, and foam-blowing agents. Halons are effective, clean firefighting agents in wide use in portable extinguishers and fixed installations. CFCs are released in processes such as chemical production, foam manufacturing, electronic and metal component cleaning, and medical product sterilization. It has often been accepted practice to vent CFCs and halons to the atmosphere when servicing equipment such as refrigeration units or fire protection systems. Venting was often used because of the relatively low cost of new replacement agents and the unknown impact on stratospheric ozone. The practice of venting CFCs and halons to the atmosphere is decreasing due to concerns about ozone depletion, the costs of replacement agents, and, to a certain extent, global warming. Increased CFC and halon costs are caused by the reduced production under the Montreal Protocol quotas and a Federal CFC tax that increases over time and is based on ozone depletion potentials (Figure 1). Current estimates are that $5 billion in CFC excise taxes will be collected over the next 5 years. Beginning in 1991, halons will be taxed at 25 cents/lb. In 1994 the halon tax will be set at $2.65/lb times ODP. Thus, recovery and reuse are both environmentally and economically sound.

Because of the past industry practice of releasing halocarbons into the atmosphere, equipment for their recovery, recycling, reclamation, and/or reuse was not in demand. The number of companies making recovery/recycling equipment or providing recycling and reclamation services is now rapidly expanding to meet the growing demand.

C. SCOPE/APPROACH

The scope of this effort was to conduct a market survey of all known equipment or services available for recovering/recycling of CFCs, halons, and related materials. Herein the term "halocarbon" is used as a generic term for those substances considered to be halogenated hydrocarbons. The results of this survey include technical information about the equipment or service, cost, and availability. An evaluation and rating of categories of equipment to perform specific functions is also included. It is based strictly on claims by the equipment manufacturers. No attempt was made in this study to verify equipment performance.

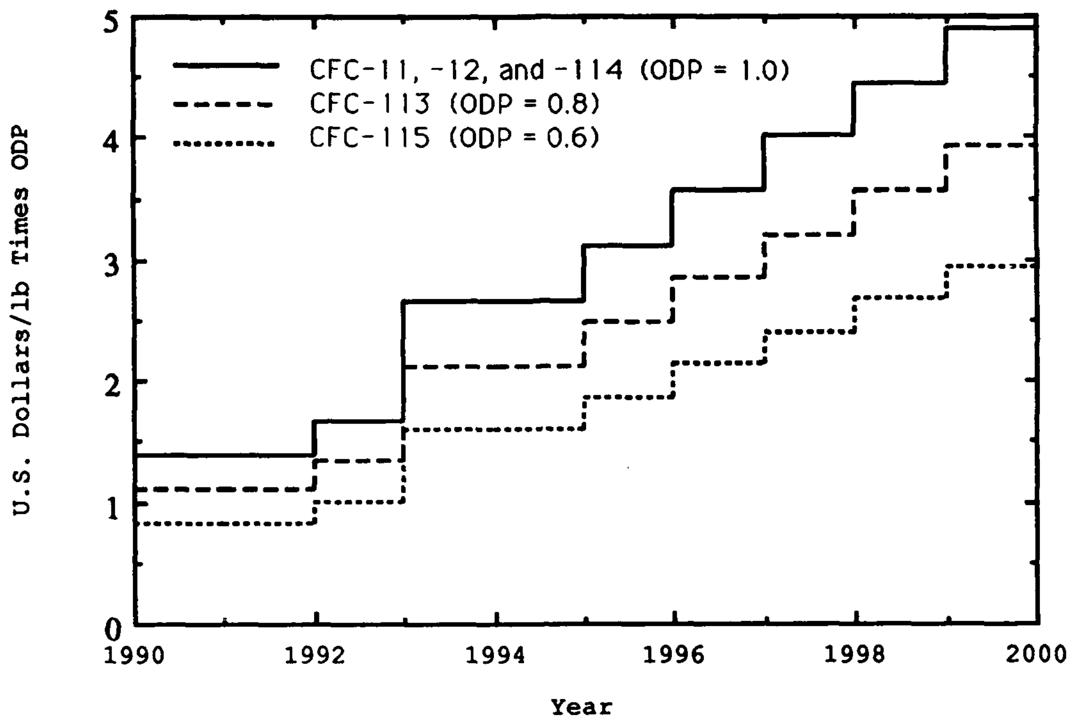

Figure 1. U.S. Tax Imposed on Manufacturers and Importers Who Sell CFCs.

Companies known to be involved in halocarbon recovery/recycling were requested to provide information on their products and/or services. The list of 34 companies (32 in the U.S. and 2 in Canada) included in Table 1 was developed from an initial list provided by the United States Environmental Protection Agency (EPA), Division of Global Change, Washington, DC, and was augmented through industry publications, literature, and contacts. The data gathered from these companies were reviewed, evaluated, and put in tabular form for ease of comparison.

TABLE 1. HALOCARBON RECOVERY/RECYCLING/RECLAMATION EQUIPMENT MANUFACTURERS AND SERVICES SUPPLIERS.

Manufacturer	City	State
Appliance Recycling Centers of America	St. Paul	MN
Applied Ecological Systems	Hazelhurst	GA
Carrier Corp.	Syracuse	NY
Cerberus Pyrotronics	Cedar Knolls	NJ
Corporate Consultants	Abilene	TX
Davco Manufacturing Company	Easton	PA
Draf Tool Co., Inc.	Bedford Hill	NY
Du Pont Freon Products Div.	Wilmington	DE
Ener Craft, Inc.	Austin	TX
Everco Industries, Inc.	St. Louis	MO
Frick Co.	Waynesboro	PA
Gill-Fam Manufacturing, Inc.	Kingston	Ontario CANADA
Getz Manufacturing	Peoria	IL
Great Lakes Chemical Corp.	Lafayette	IN
High Frequency Products	Miami	FL
IG-LO	Hernando	MS
Industrial Chiller Services	Friendswood	TX
Intermark Environmental Science	Reno	NV
James Kamm Technologies	Toledo	OH
MDI	Wheat Ridge	CO
Murray Corporation	Cockeysville	MD
National Refrigerants, Inc.	Plymouth Meeting	PA
Omega Recovery Services	Whittier	CA
Production Control Units, Inc.	Dayton	OH
Refrigerant Technologies, Inc.	York	PA
Refrigerant Recovery Systems, Inc.	Tampa	FL
Robinair Division Sealed Power Corp.	Montpelier	OH
Serv-I-Quip, Inc.	Downing Town	PA
Technical Chemical Co.	Dallas	TX
Tritop, Inc.	Lachine	Quebec CANADA
ThermaFlo	Springfield	MA
Thermal Engineering Co.	Toledo	OH
Van Hook Service Co. Inc	Rochester	NY
Van Steenburgh Engineering Laboratories	Denver	CO
White Industries	Indianapolis	IN
Wynn's Climate Systems, Inc.	Fort Worth	TX

SECTION II
HALOCARBON USES

Halocarbon usage falls into five key technical sectors: (1) refrigeration, air-conditioning, and heat pumps, representing 25 percent of the global consumption of controlled CFCs; (2) rigid and flexible foam production, representing 25 percent; (3) electronic, degreasing, and dry cleaning solvents, representing 16 percent; (4) aerosol, sterilants, and miscellaneous uses, representing 34 percent; and (5) halon fire-extinguishing agents, representing less than 3 percent of the total consumption. Approximately 1 million metric tons of CFCs and 25,000 metric tons of halon were consumed worldwide in 1986 (Reference 2).

Halocarbons have a wide application due to their inertness, low toxicity, cleanliness, and, until recently, low cost. Current technologies use CFC-11, -12, -113, -114, and -115 as working fluids in air conditioners, refrigerators, and freezers. They are used in home, business, automobile, aircraft, and ship air-conditioning; commercial refrigeration; refrigerated trucks; water coolers; commercial chillers; and similar applications. Though CFC-115 is not generally used by itself as a refrigerant, it is the major component (51.1 percent by weight) combined with HCFC-22 in the azeotropic mixture R-502, and used in commercial refrigeration equipment (Reference 2). In addition to being widely used by itself, CFC-12 is the major constituent (73.8 percent by weight) combined with HFC-152a in the azeotropic mixture R-500, which is used in chillers. Refrigeration processes form the largest global consumption category for the controlled CFCs. Several alternative chemicals are now being introduced to compensate for the loss of these refrigerants. These alternatives include HCFCs-22, -123, HFC-134a, and some azeotropic mixtures. In the long term, potential substitutes could include HFCs-32, -125, -152a, and -143a and HCFCs-124, and -142b (Reference 2).

CFC-11 and -12 are also used to create cells in plastic foams. Foams can be generally classified as rigid or flexible. Rigid foams are used as insulating and packaging materials. Flexible foams are used in mattresses, car seats, foam cushions, and related products. Extruded foam boards and panels of similar materials are manufactured with the same blowing agents and are used as insulation in residential and commercial buildings throughout the world. Alternative foaming technologies and new alternatives are being developed to meet the growing demand for foam products.

CFC-113 is used mainly as a cleaning solvent in the electronics, precision metal component manufacturing, and dry cleaning industries. Alternative cleaning substitutes include higher boiling point alternative chemicals currently under development and new cleaning technologies such as aqueous and terpene-based cleaning processes.

CFC-12 is used as a gaseous aerosol propellant for a wide variety of products, such as paints, adhesives, hair spray, and certain medical products. CFC-12 is also used as a sterilization agent for heat-sensitive medical devices. Propellent substitutes are available and in wide use in the U.S.; however, more research and development are required to identify alternatives to CFC for medical sterilization.

Halon 1011, 1211, 1301, and 2402 are bromine containing halocarbons that exhibit exceptional firefighting effectiveness. They are electrically nonconductive, dissipate quickly without leaving a residue, have three-dimensional capabilities, and are relatively nontoxic at extinguishing concentrations. Alternatives are being investigated by a number of researchers; USAF-sponsored work has identified several promising candidates (References 3-7), Du Pont recently announced HCFC-123 and HFC-125 as potential substitutes, and Great Lakes Corporation has announced HBFC-22B1 as a possible alternative.

Production restrictions on CFCs will result in increased energy consumption and operations costs. Furthermore, many available refrigerant and foam-blowing agent substitutes are less efficient and more expensive. However, the excise tax on ozone-depleting substances will generate a market for the higher priced substitutes and provide an economic incentive to recycle controlled substances. The latter is especially significant in light of the existing large global stock of equipment and processes that depends on CFCs and halons to provide energy- and cost-efficient cooling, refrigeration, insulation, cleaning, and fire-extinguishing capabilities. Recovery, recycling, and reclamation (R/R/R) of halocarbons will provide industry the opportunity to "postpone or even avoid entirely the need to prematurely retire or retrofit equipment requiring these chemicals" (Reference 8).

R/R/R technologies must also be addressed and evaluated as new alternative chemicals and equipment are developed. The alternatives are necessary for a timely and smooth transition away from the existing halons and CFCs; however, they must be used prudently. Although new chemicals have a reduced stratospheric ozone depletion potential (ODP), accelerated emission rates could cause increased atmospheric chlorine levels, with subsequent production restrictions on the alternatives. EPA has indicated that restrictions on alternatives could occur without a prudent use plan that includes R/R/R technologies.

SECTION III
DEFINITIONS AND HALOCARBON PROPERTIES

For purposes of this study, the term "halocarbon" denotes CFCs, halons, and related materials (including CFC and halon alternatives). These carbon compounds contain fluorine, chlorine, and/or bromine. Hydrogen may also be present. The industry survey request for this study specifically identified but did not limit response to equipment or services for CFCs-11, -12, -22, -113, -114, -115, -500, and -502 and for Halons 1011, 1211, 1301, and 2402. Table 2 lists these materials and their proposed alternatives. Tables 3, 4, and 5 list chemical and physical properties of these selected halocarbons.

Halocarbons and their alternatives have both CFC and halon numbers, as shown in Table 2. Industry practice has been to denote bromine-containing compounds as "halons" and chlorine-containing compounds as "CFCs." Other halocarbon number prefixes are also used. For example, compounds containing only fluorine, chlorine, and hydrogen substituents are designated "hydrochlorofluorocarbons" (HCFCs). The designation "Halocarbon No." is used throughout this report to refer to CFC (chlorofluorocarbon), HCFC (hydrochlorofluorocarbon), HFC (hydrofluorocarbon), BFC (bromofluorocarbon), BCFC (bromochlorofluorocarbon), HBFC (hydrobromofluorocarbon), and HBCFC (hydrobromochlorofluorocarbon) numbers.

The halocarbon numbering system was originally developed by Du Pont as a code when CFCs (Freon®)were first developed in the late 1930s and was later expanded and formalized into a standard by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE). In this system, the first number gives the number of carbon atoms minus one, followed by (in order) the number of hydrogen atoms plus one and the number of fluorine atoms. All unspecified atoms are chlorines. An initial zero (indicating a one-carbon compound) is dropped. For example, CFC-12 has one carbon atom (initial zero dropped), no hydrogen atoms (0+1=1), two fluorine atoms and, by default, two chlorine atoms, for the formula CF_2Cl_2. Note that several isomers may have identical halocarbon numbers. To distinguish these isomers a letter is added based on the symmetry of the molecule. Absence of a letter indicates the most symmetrical isomer, an "a" indicates the next most symmetrical isomer, "b" the next, etc. The designation "Bn", where "n" is an integer, after the halocarbon number indicates that a chlorine atom has been substituted by n bromine atoms. For example, Halocarbon 22B1 designates $CHBrF_2$, bromodifluoromethane.

TABLE 2. HALOCARBONS ADDRESSED IN THIS STUDY.

Halocarbon No.	Halon No.	Chemical Formula	IUPAC Chemical Name
Group 1 Chemicals[a]			
11	113	CCl_3F	Trichlorofluoromethane
12	122	CCl_2F_2	Dichlorodifluoromethane
113	233	CCl_2FCClF_2	1,1,2-Trichloro-1,2,2-trifluoroethane
114	242	$CClF_2CClF_2$	1,2-Dichloro-1,1,2,2-tetrafluoroethane
115	251	$CClF_2CF_3$	1-Chloro-1,1,2,2,2-pentafluoroethane
Group 2 Chemicals[a]			
12B1	1211	$CBrClF_2$	Bromochlorodifluoromethane
13B1	1301	$CBrF_3$	Bromotrifluoromethane
114B2	2402	CF_2BrCF_2Br	1,2-Dibromo-1,1,2,2-tetrafluoroethane
Others			
500	Azeotrope Mixture of 74% (by weight) CFC-12 and 26% HFC-152a.		
502	Azeotrope Mixture of 49% (by weight) HCFC-22 and 51% CFC-115.		
30B1	1011	CH_2BrCl	Bromochloromethane
Proposed Alternatives			
22	121	$CHClF_2$	Chlorodifluoromethane
123	232	$CHCl_2CF_3$	2,2-Dichloro-1,1,1-trifluoroethane
124	241	$CHClFCF_3$	2-Chloro-1,1,1,2-tetrafluoroethane
125	25	CHF_2CF_3	Pentafluoroethane
134a	24	CH_2FCF_3	1,1,1,2-Tetrafluoroethane
141b	212	CH_3CCl_2F	1,1-Dichloro-1-fluoroethane
142b	221	CH_3CClF_2	1-Chloro-1,1-difluoroethane
143a	23	CH_3CF_3	1,1,1-Tetrafluoroethane
152a	22	CH_3CHF_2	1,1-Difluoroethane

[a]As defined by the Montreal Protocol (Reference 1).

TABLE 3. PHYSICAL/CHEMICAL PROPERTIES OF SELECTED CFCs.[a]

Property	Halocarbon Number						
	11	12	113	114	115	500	502
Boiling point, °C	23.83	-29.77	47.57	3.80	-38.0	-33.5	-45.6
Critical density, g/mL	0.554	0.556	0.576	0.582	0.596	-	-
Critical pressure, Mpa	4.410	4.136	3.41	3.26	3.12	4.42	4.26
Critical temperature, °C	198.1	111.8	214.1	145.7	80.0	105.6	90.0
Dielectric constant	2.28	2.13	2.41	2.26	-	-	-
Dipole moment, Debye	0.45	0.25	1.44	-	0.52	-	-
Heat of formation, KJ/mol	-301.33	-461.7	-710.9	-900.1	-1108.76	-	-
Heat of vaporization, KJ/mol	25.0	19.98	28.39	23.26	19.46	18.8	17.7
Liquid density (@ 25 °C), g/mL	1.464	1.31	1.56	1.53	1.57	1.14	-
Liquid heat capacity, J/mol•K	121.55	117.4	171	174	184.1	-	-
Liquid thermal conductivity, W/m•K	0.085	0.069	0.064	-	-	-	-
Liquid viscosity, N•s/m^2 (x10^{-4})	4.3	2.54	6.8	3.6	1.93	-	-
Melting (freezing) pt., °C	-111.0	-158.0	-35.0	-94	-106.0	-158.9	1.22
Molecular weight, g/mol	137.37	120.91	187.38	170.92	154.47	99.3	111.6
Refractive index	1.374	1.1834	1.359	1.29	1.268	-	-
Vapor density (@ 25 °C), g/mL	0.0056	0.0049	0.0077	0.0070	0.0063	0.0041	0.0046
Vapor heat capacity, J/mol•K	77.91	72.3	126.2	121.6	106.0	-	-
Vapor pressure, MPa	0.148	0.91	0.248	0.213	0.929	1.07	1.59
Vapor thermal conductivity, W/m•K	0.087	0.071	0.0078	-	-	-	-
Vapor viscosity, N•s/m2	4.4E-3	2.59E-4	1E-5	-	1.25E-5	-	-

[a]Values were taken from the NMERI Halocarbon Database© Ver. 2.0 (References 6 and 7).

TABLE 4. PHYSICAL/CHEMICAL PROPERTIES OF SELECTED CFC ALTERNATIVES.[a]

Property	Halocarbon Number								
	22	123	124	125	134a	141b	142b	143a	152a
Boiling point, °C	-40.83	24.0	-12.0	-48.5	-26.5	32.0	-10.0	-47.6	-24.7
Critical density, g/mL	0.513	0.54	0.541	-	0.513	0.43	0.435	0.435	0.368
Critical pressure, Mpa	4.977	3.85	3.63	3.58	4.067	4.72	4.12	3.76	4.496
Critical temperature, °C	96.1	185	122	66.3	101.1	210.3	137.1	73.1	113.5
Dielectric constant	6.11	-	-	-	-	-	-	-	34.4
Dipole moment, Debye	1.42	-	-	-	-	-	2.21	2.23	2.3
Heat of formation, KJ/mol	483.9	-	-	-	-904.2	-	-529.3	-745.6	-500.8
Heat of vaporization, KJ/mol	18.79	26.3	22.9	19.1	22.4	25.87	22.4	-	14.7
Liquid density (@ 25 °C), g/mL	1.174	1.462	1.38	1.25	1.203	1.232	1.113	0.940	0.950
Liquid heat capacity, J/mol•K	101.1	155	154	151	146	135	131.3	-	110
Liquid thermal conductivity, W/m•K	0.086	0.100	0.025	0.0214	0.0783	0.028	0.028	-	0.0346
Liquid viscosity, N•s/m^2 ($x10^{-4}$)	2.3	4.49	3.14	1.04	2.02	4.09	3.2	-	2.39
Melting (freezing) pt., °C	-160.0	-107	-199	-103	-101	-103.5	-131	-	-117
Molecular weight, g/mol	86.47	152.93	136.48	120.02	102.3	116.95	100.5	84.04	66.05
Refractive index	1.256	-	1.265	-	-	1.36	-	-	1.3
Vapor density (@ 25 °C), g/mL	0.0035	0.0063	0.0068	0.00491	0.00418	0.00467	0.00411	0.00344	0.0027
Vapor heat capacity, J/mol•K	52.89	102.3	112.6	84.8	87.11	88.58	82.68	78.2	67.78
Vapor pressure, MPa	1.044	0.0913	90.8	1.33	0.569	0.080	0.3	-	0.5431
Vapor thermal conductivity, W/m•K	0.09	0.0104	0.0034	0.00369	0.0145	0.0046	0.011	-	0.00377
Vapor viscosity, N•s/m2	1.23E-5	4.18E-4	1.2E-5	1.5E-5	1.25E-5	1.29E-4	-	-	-

[a]Values were taken from the NMERI Halocarbon Database© Ver. 2.0 (References 6 and 7).

TABLE 5. PHYSICAL/CHEMICAL PROPERTIES OF SELECTED HALONS.[a]

Property	Halon Number			
	1011	1211	1301	2402
Boiling point, °C	68.06	-3.97	-57.8	47.26
Critical density, g/mL	-	-	0.745	0.790
Critical pressure, Mpa	-	-	3.96	3.4
Critical temperature, °C	297.1	-	67	214.5
Dielectric constant	-	-	-	2.34
Dipole moment, Debye	-	-	0.65	-
Heat of formation, KJ/mol	-	-471.9	-642.7	-
Heat of vaporization, KJ/mol	34.0	23.0	17.69	27
Liquid density, g/mL	1.9344	1.850	1.499	2.16
Liquid heat capacity, J/mol•K	-	125.6	129.7	181
Liquid viscosity, N•s/m^2 ($x10^{-4}$)	-	-	1.57	7.2
Melting (freezing) pt., °C	-87.9	-161	-168.0	-110
Molecular weight, g/mol	129.38	165.36	148.91	259.82
Refractive index	1.484	-	1.238	1.367
Vapor density (@ 25 °C), g/mL	0.0053	0.0068	0.0061	0.0106
Vapor heat capacity, J/mol•K	52.63	74.43	69.25	-
Vapor pressure at 25 °C, MPa	-	0.227	1.72	0.0375
Vapor thermal conductivity, W/m•K	-	-	0.043	-
Vapor viscosity, N•s/m2	-	-	1.5E-4	7.2E-4

[a]Values were taken from the NMERI Halocarbon Database© Ver. 2.0 (References 6 and 7).

The halon numbering system was introduced by the Army Corps of Engineers as a simpler means of identifying this family of compounds. The halon numbering system lists, in order, the number of carbon, fluorine, chlorine, bromine, and iodine atoms. The remaining sites are assumed to be filled with hydrogen atoms. Trailing zeros are dropped; thus, Halon 12 is CH_2F_2, difluoromethane.

The Ozone Depletion Potential (ODP) is a number giving the calculated relative extent to which a particular chemical compound depletes stratospheric ozone on either a per-molecule or a per-pound emitted basis. Usually the per-pound basis is used, and that is the basis used here. ODPs are rigorously calculated using atmospheric models (Reference 9). CFC-11 is arbitrarily assigned an ODP of 1.0. Higher numbers indicate a greater potential to deplete stratospheric ozone. The ODPs of the halocarbons addressed in this study are shown in Table 6.

The Global Warming Potential (GWP) is a number giving the calculated relative extent to which a particular chemical compound contributes to global warming on a per pound emitted basis. GWPs are rigorously calculated using atmospheric models (Reference 10). CFC-11 is arbitrarily assigned a GWP of 1.0. Higher numbers indicate a greater potential to contribute to global warming. GWPs are also shown in Table 6.

Many terms are currently used throughout the industry to refer to recovering halocarbons that exist in air-conditioning, refrigerating, cleaning, or firefighting equipment and transferring, storing, purifying, reclaiming, and reusing these materials to prevent atmospheric release. The terminologies used may have different meanings to different people. The Air-Conditioning and Refrigeration Institute (ARI) has recognized this problem and has adopted definitions to standardize their use and meaning. Those definitions are given below:

1. Recovery: To remove refrigerant (halocarbon) in any condition from a system and store it in an external container without necessarily testing or processing it in any way.

2. Recycle: To reduce contaminants in used refrigerant (halocarbon) by oil separation and single or multiple passes through devices that reduce moisture, acidity, and particulate matter, such as replaceable core filter-driers. This term usually applies to procedures implemented at the field job site or at a local service shop.

TABLE 6. OZONE DEPLETION AND GLOBAL WARMING POTENTIALS AND LIFETIMES FOR SELECTED HALOCARBONS.[a]

	Substance	ODP	GWP	Lifetime, yrs.
Group 1[b]				
	CFC-11	1.0	1.0	75
	CFC-12	1.0	3.1	148
	CFC-113	0.8	1.4	89
	CFC-114	1.0	3.9	185
	CFC-115	0.6	7.6	380
Group 2[b]				
	Halon 1211	3.0	-	107
	Halon 1301	10.0	0.8	107
	Halon 2402	6.0	-	28
Other				
	Halon 1011	-	-	-
	R-500	0.66	2.3	110
	R-502	0.20	4.1	201
Alternatives				
	HCFC-22	0.05	0.36	14
	HCFC-123	0.02	0.019	1.5
	HCFC-124	0.02	0.096	6.0
	HFC-125	0.0	0.58	26.4
	HFC-134a	0.0	0.27	14.4
	HCFC-141b	0.01	0.094	7.0
	HCFC-142b	0.06	0.037	17.9
	HFC-143a	0.0	0.74	39.5
	HFC-152a	0.0	0.03	1.6

[a]Values were averaged from Reference 10.
[b]As defined by the Montreal Protocol (Reference 1).

3. Reclaim: To reprocess refrigerant (halocarbon) to new product specifications, by means that may include distillation. Chemical analysis of the refrigerant will be required to determine whether appropriate product specifications are met. This term usually implies the use of processes or procedures available only at a reprocessing or manufacturing facility.

The ARI definitions for recovery, recycling, and reclamation (R/R/R) are adopted and used throughout this report for all halocarbons, and the abbreviation R/R/R is used throughout this report to refer to recovery, recycling, and reclamation.

SECTION IV
MARKET SURVEY

A. INTRODUCTION

As a result of the Montreal Protocol limitations on ozone-depleting chemicals, the halocarbon R/R/R equipment industry is rapidly expanding. A comprehensive list of companies offering equipment or services for one or more of the R/R/R functions for halocarbons was compiled. The effort began with an initial list provided by the EPA, which was added to through industry publication reviews and contacts. The expanded list, including names, addresses, telephone numbers, and technical contacts is included in Appendix A.

Information was solicited from each company by a letter that requested specific data on their product/service. The letter is included in Appendix B. A similar request for information was also published by the Air Force Engineering and Services Center (AFESC), Tyndall AFB, Florida, in the Commerce Business Daily (30 March 1990).

In order to condense the information obtained from the various manufacturers, suppliers, and service organizations into a form that permits easy comparisons of the capabilities of equipment and services, tables have been developed and are included in Appendix C.

B. HALOCARBON RECOVERY/RECYCLING/RECLAMATION REQUIREMENTS

The halocarbon family includes CFCs, HCFCs, halons, and their alternatives. The requirements for the CFC and halon subgroups of the halocarbon family will be discussed separately.

1. CFCs

Equipment using CFCs as coolant fluids ranges in size from mobile air conditioners (automobiles) and residential refrigerators requiring a few ounces or pounds to very large commercial refrigerators and air conditioners requiring hundreds of pounds. Table 7 gives estimated CFC contributions to ozone depletion by application; Table 8 shows estimated CFC contributions to ozone depletion by product (i.e., the type of CFC). The R/R/R

TABLE 7. GLOBAL CFC CONTRIBUTION TO OZONE DEPLETION BY APPLICATION.[a]

Application	Usage,%	Usage Adjusted for ODP,%
Refrigeration	34	21
Auto AC	13	19
Foam Products	18	26
Solvent	16	19
Polymer	11	2
Medical	2	3
Aerosol	2	3
Other	4	7

[a]Reference 11.

TABLE 8. GLOBAL CFC CONTRIBUTION TO OZONE DEPLETION BY PRODUCT.[a]

Product	Usage, %	Usage Adjusted for ODP, %
CFC-11	19	28
CFC-12	33	48
CFC-22	26	2
CFC-113	17	20
CFC-114	1	1
Other	4	1

[a]Reference 11.

requirements for the halocarbons used in the electronics, cleaning, aerosol, sterilant, and foam-blowing sectors are beyond the scope of this effort and are not included in this report.

Past practice in the refrigeration and air-conditioning industry has been to release CFCs into the atmosphere during installation, testing, servicing, and replacement of equipment. A significant reduction in CFCs emissions can be realized with the recovery, recycling, and reuse of CFCs (Reference 12).

Recovered CFCs usually contain some contaminants. The contaminants usually fall into one of five categories: particulates, oils, moisture, acids, and noncondensable gases. The amount of contaminants present in recovered CFCs largely depends on why the CFCs were removed from the system. If they were removed for normal servicing or leak repair, the level of contamination is generally low. If the material was removed because of a compressor burnout in a hermetically sealed system, the contamination level could be high.

Removable/replaceable core filters are successful in removing most particulates, moisture, and acids; however, multiple passes may be required to achieve the desired purity level. Visual indicators on some filters can indicate moisture and acid levels by color changes; however, these indicators usually cannot determine and certify the exact purity levels achieved.

Two types of R/R/R equipment and services are generally available. The first is portable equipment, which varies in complexity and level to which one can recycle or purify the CFC for reuse. The CFC is usually temporarily recovered in a built-in or nearby storage tank and is recharged into the system after service/maintenance is complete. The second type includes larger plant-based units or much less portable distillation units, which can reclaim the recovered CFC to specified purity levels. Because CFCs are highly volatile, purification by distillation leaves behind lower boiling point contaminants such as lubricating oils, organic acids, and water.

2. Halons

Halons are used almost exclusively as fire suppression agents. The most commonly used agents are Halons 1211, 1301, and 2402. Halon 1011 use was eliminated with the introduction of Halon 1211. The share of production and use worldwide for year 1986 is estimated at 56 percent Halon 1211, 40 percent Halon 1301, and 4 percent Halon 2402 (Reference 13). Halon 2402 has limited use in the U.S., but is more widely used in Europe. Halon 1211 is used primarily in manual-application hand-held, wheeled, and truck-mounted extinguishers because its physical properties make it ideal for streaming applications. Halon 1301 is used primarily as a total-flood agent to protect enclosed spaces by introduction to give a 5 to 7 percent by volume concentration. It also has limited use in hand-held extinguishers for applications requiring cleanliness and a gaseous agent. Halon 2402, a streaming agent, is used in only a few specialized application systems in the U.S.: protection of off-road mobile equipment, commercial oil fryers (deep fat), and floating roof petroleum storage tanks. Most Halon 1211 atmospheric releases result from firefighter training with manual equipment. Most Halon 1301 releases occur during system certification testing and accidental system discharges. Halon emissions also occur when servicing equipment and during fire extinguishment. Progress has been made in reducing emissions of Halon 1211 by reducing training use and by better servicing practices for portable fire extinguishers. Simulated test gases have been developed for testing and certifying Halon 1301 systems. Use of alternate methods for firefighter training, minimization of "false dumps," development of "best essential uses," and R/R/R techniques for servicing could dramatically reduce halon emissions.

The purity requirements for recycled Halon 1211 have not been established. The primary contaminant of concern is moisture, which forms acids causing corrosion and degradation of system integrity. Tests of up to 6 months duration show no corrosion of mild steel and aluminum when the water content of Halon 1211 is below the water solubility limit (Reference 14). The water solubility of Halon 1211 is between 70 and 80 parts per million (ppm) from -10 °C to 20 °C (Reference 15). It has been concluded that free water (i.e., water content higher than the water solubility level) must be present to cause corrosion of steel and aluminum. The corrosion process consumes the free and soluble water in the Halon 1211 to give a water content of about 5 ppm, at which point no further corrosion occurs.

Halon 1301 worldwide usage for 1986 is estimated at 7 percent for fires, 23 percent for emissions considered to be controllable, and 70 percent banked in systems or stored (Reference 13). "Controllable" emissions include accidental discharges, discharge testing, training, and service losses. Discharge testing has been curtailed significantly and replaced with other test techniques and procedures. Reduction in emissions can be realized through recovery and recycling of Halon 1301 for servicing of systems or end-of-life system dismantling. Accidental discharges can be reduced with improved detector and control systems and with better training and maintenance procedures. Most Halon 1301 systems are "pressurized" with dry nitrogen (usually to 360 or 600 lb/in.^{2}) to achieve the desired discharge characteristics for a particular application. Some of the nitrogen used for pressurization dissolves in the liquid Halon 1301. Apparently, no degradation of fire suppression properties of the Halon 1301 due to the nitrogen occurs as long as the proper concentration of agent in the enclosed space is achieved.

Recovery and recycling equipment for Halon 1301 must be designed to operate with the high vapor pressure of Halon 1301, plus the nitrogen gas pressurization. As with other CFCs and halons, capabilities to remove contaminants such as water, particulates, acids, and oils are required. The necessity to remove all of the nitrogen is not clear, particularly if the recycled Halon 1301 is going to be used again in a pressurized system.

Halon 2402 has a higher boiling point than that of Halon 1211 and probably can be easily handled by any equipment capable of recovering and recycling Halon 1211. Since Halon 2402 represents only 4 percent of the world halon fire suppressant production/use, and significantly less in the U.S., requirements for R/R/R for this agent are limited.

Halon 1011, more commonly known as chlorobromomethane (CB), was used as a streaming fire-extinguishing agent by the military before the introduction of Halon 1211. Military use of Halon 1011 has been eliminated. Recently, the military specification applicable to this material was cancelled, and military commands were instructed to dispose of material on hand through Defense Reutilization and Marketing Office (DRMO) channels. Therefore, R/R/R equipment needed to handle Halon 1011 is not required by the USAF.

C. SURVEY RESULTS

The key features and capabilities of equipment and services provided for R/R/R of halocarbons are included in the tables in Appendix C. The tables are divided into three categories. The first category is equipment for R/R/R of CFCs. Although the search identified 25 companies that make a total of 54 models of equipment, which perform one or more of the R/R/R functions (Table C-1), note that only 12 of these models are currently certified by UL for recycling of CFC-12 from automotive air conditioners.

The second category is equipment for R/R/R of halons. Five companies that make a total of six models of equipment, which perform one or more of the R/R/R functions for halons, were identified (Table C-2). Twelve units of one model have been evaluated by the U.S. Navy at 12 test sites. A certification program is under development by UL for Halon 1211 R/R/R units and is further discussed in Section VI.

In the third category, five companies that perform bulk reclamation services at central location(s) were found (Table C-3). One company recovers refrigerants (R-12 and R-22) from discarded household appliances (refrigerators, freezers, and air conditioners) and recycles them for reuse in repaired appliances. They currently have three locations: St. Paul, MN; Milwaukee, WI, and Jacksonville, FL.

The halocarbons that can be handled by the particular equipment or services are indicated in Appendix C. The information contained in the tables about the capabilities of specific equipment or services is strictly that claimed by the company providing the information. It is not within the scope of this task to verify the validity of the information provided or claims made by the responding companies.

Brochures and catalogue cuts describing the R/R/R equipment were collected from the manufacturers in performing this study. A printed copy of this collection can be obtained from NMERI for a fee to cover photo copying and administrative costs. (Contact NMERI/APT, University of New Mexico, Albuquerque, NM 87131, attn: APT Division, R/R/R Study.) Brochures from individual companies can be obtained by contacting the companies directly using the list provided in Appendix A.

Most of the companies surveyed manufacture portable equipment for on-site or local shop use in recovering and recycling CFCs, primarily for the mobile air-conditioning (auto) and stationary air-conditioning and refrigeration market. A few companies have semiportable or large stationary equipment targeted for CFC recovery and recycling for large industrial refrigeration and air-conditioning units and for factory assembly line use. A limited number of units for recovery and, in particular, recycling of halons exist. Some of the general capabilities of equipment being manufactured for R/R/R of halocarbons are described below in categories according to the ARI definitions of recovery, recycling, and reclamation.

1. Recovery

Recovery is removing a halocarbon from a system and storing it in an external container without purifying or processing it. The simplest method of achieving recovery is to use hoses and fittings and a pressurizing gas to provide a pressure differential that will cause the halocarbon to flow from the system to an external container at lower pressure. This method, used more commonly with halons, will cause contamination of the halocarbon by the gas used to effect the transfer. Most of the pressurizing gas can be purged from the system with some accompanying halocarbon losses. The effect of the transfer gas contamination must be determined by the individual halocarbon application.

The equipment, specified for "recovery only" in the tables of Appendix C, affects transfer of the halocarbon either by use of a liquid pump, a vapor compressor, or both. A liquid pump permits a faster rate of recovery than that allowed by vapor compression. The disadvantage is that the vapor "heel" in the system cannot be recovered. Although the combination of a liquid pump and a vapor compressor, either as separate units to be used in sequence or in a single recovery unit, achieves the faster transfer rate and removal of the vapor heel, it is more expensive to buy and operate.

Fentek, Inc., is developing a reusable collection bag that would hold about three pounds of refrigerant vapor. The advantage of the bag collector is that it could be used in remote locations for refrigerant collection, then brought back to a central location for retrieval with conventional R/R/R equipment. Fentek's development work is funded by IG-LO, Inc., and is expected to be complete by the end of 1990.

Six of the companies surveyed make a total of 10 models of halocarbon "recovery only" equipment. The key features and capabilities can be found in Tables C-1 and C-2.

2. Recycling

Recycling involves recovery of used halocarbons and removal of contaminants by oil separation and single or multiple passes through devices that reduce moisture, acids, oils, and particulates. Recycling usually implies a process conducted at the field job site or in a local service shop. Contaminants are usually removed with replaceable core filter-driers. Some recovery/recycling units achieve certain purity levels by recirculating the recovered halocarbon through the filter process several times to remove the contaminants.

In the recycling category, 19 companies that make 41 models were identified. Most use filter-driers to remove particulates, acids, and moisture. Qualitative moisture levels are usually determined with a sight glass with a "dry-eye" color change moisture indicator. Some systems also have a sight glass for visual check for halocarbon clarity. Many units have graduated collectors for the oil separator, which facilitate replacement of the lubricating oil in the system from which the halocarbon was removed. Some units use distillation for oil separation, and a few use distillation for removing other contaminants. Most units have either a manual or automatic purge of noncondensable gases. Of the 41 models identified for use with automotive air conditioners, 12 are currently certified by UL for compliance with UL Standard 1963.

One model is claimed by the manufacturer to achieve ARI 700-88 purity requirements through a patented distillation process. Another manufacturer claims to achieve ARI 700-88 purity requirements through a patented multistage, single-pass filter. Another manufacturer has a patented self-cleaning filter system that is claimed to reduce filter replacement costs drastically. One manufacturer uses a patented "velocity gradient" chamber to separate contaminants.

In general, the R/R/R units remove contaminants from the halocarbon to a given qualitative level. Exact purity can be determined only by detailed laboratory analysis techniques, which are relatively expensive. This is generally not cost-effective for smaller quantities of halocarbons. When high purity must be obtained, the next level in the R/R/R ladder, reclamation, is appropriate.

3. Reclamation

Reclamation implies processing used halocarbons to new-product specifications. Distillation is usually required to reclaim used halocarbons to new-product purity. Chemical analysis of the reclaimed halocarbon is required to certify that purity specifications have been met. Because of the complexity, size, and cost of equipment and the need for analysis of the reclaimed product, reclamation is usually done in bulk at a central manufacturing or reprocessing facility. Use of central facilities requires the recovery of the used halocarbons into containers that are shipped to the facility for reclamation.

Four of the companies surveyed provide bulk reclamation services (Table C-3). All of these will test the reclaimed halocarbon to certify purity. A fifth company listed in Table C-3 provides on-site recovery and recycling with a large (3000-pound) distillation unit, which is intended for use with large industrial refrigeration/air conditioning systems containing several hundred pounds of refrigerant. Purity can be certified by taking a sample of recycled refrigerant and sending it to a testing laboratory for analysis.

As indicated in the discussion in the "Recycling" section above, two companies claim to manufacture equipment that can recycle certain halocarbons to ARI 700-88 purity standards. If that is the case, these could be classified as reclamation units. If purity certification is required, however, the economics of laboratory testing of samples from small quantities becomes a major consideration.

4. Operation, Service, and Training Aids

The R/R/R equipment identified and included in the survey varies in complexity. Some equipment performs many functions automatically once connected to the system to be serviced and activated. Other units have relatively simple functions that must be activated manually with the entire operation monitored throughout the recovery/recycling processes.

Operation, service, and training aids are available for most of the units surveyed. Some manufacturers send out manuals with the technical information on their units. Most do not. Accordingly, some manufacturers provide video tapes along with the manuals for training, and some offer training courses at their facilities. Because of the variation in complexity of the units, training requirements will vary.

D. SUMMARY

Considerable effort was expended in this study to identify and contact every U.S. company involved in the R/R/R of halocarbons; two Canadian companies were also contacted. The information included from each company is reported as received. This field is rapidly advancing as a result of the increasing demand for reduction of halocarbon emissions, and new capabilities and products are appearing almost daily. This study can be used to indicate where needed capabilities for R/R/R are lacking and where new capabilities should be provided in the future.

SECTION V
HALOCARBON RECOVERY, RECYCLING, AND RECLAMATION CONCERNS

Recovered halocarbons can be of questionable quality. They may be contaminated with water, acids, oils, noncondensable gases, or particulates. Some contaminants (water, acid, or particulates from rust and scale) arise from moisture contamination of the system, aging and thermal degradation during storage and recycling, oils from transfer hoses and corrosion protection of metal parts, and accidental contact with foreign materials. The contamination level depends on the past history of the halocarbon including cleanliness of containers, storage time, and handling procedures, and on the R/R/R apparatus. For example, in positive displacement compressors, oil may be carried over from the compressor crankcase. This problem can be alleviated or eliminated by using a "dry" compressor, thereby preventing contamination during vapor compression.

The presence of water can result in hydrolysis. Water is only slightly soluble in halocarbons; however, free water is probably an even more serious problem. In the absence of excess water, "dry" hydrogen halides are formed and such materials may not be particularly damaging, at least to metals. On the other hand, these hydrogen halides can dissolve in excess water to form highly corrosive acids. Hydrogen bromide is formed relatively rapidly by hydrolysis; hydrogen fluoride is formed more slowly. Hydrohalic acids are common impurities in halocarbons. Such materials can damage systems and R/R/R units and have been known to cause container failure.

Particulate matter is often present from the system itself, the R/R/R equipment used, or from storage cylinders. Piping often contains metal filings, and container corrosion can give rust particles.

The recycling method used has a great influence on which contaminants are removed and to what extent. Two common methods now used for contaminant removal are distillation and filtration/sorption. Distillation equipment is usually more complex and expensive and is generally nonportable. Distillation removes both low- and high-boiling impurities and provides the highest purity. Filtration and sorption systems that remove moisture, acids, oil, and particulates from halocarbons are commercially available. Filtration and sorption are more practical than distillation for portable field units. Satisfactory removal of impurities can be effected with such simple devices as mechanical filters, silica gel, molecular sieves, and activated charcoal (Reference 16).

One must determine the cleanup required to meet halocarbon specifications, and whether the specified purity levels are really necessary. The U.S. military has considered relaxing military specifications to facilitate halocarbon reuse. Several military specifications must be evaluated and changed before recycled halocarbons, alternatives, or new technologies can be substituted.

A. REFRIGERATION AND AIR-CONDITIONING INDUSTRY

The CFC industry has done considerable work addressing impurities and needed purity levels. This work has included recycling CFCs, particularly for the automotive industry. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) has been heavily involved in work on CFC recycling, with an emphasis on meeting purity specifications for the material recycled. The chemicals section of the Air-Conditioning and Refrigeration Institute (ARI) recently released a guideline that explains good practices for use of cylinders for receipt, storage, and transportation of used refrigerants recovered from systems (Reference 17). ARI is also developing a standard to measure the performance of refrigerant R/R/R equipment. The acceptable level of purity of reclaimed, used refrigerant must be defined.

The refrigeration, air-conditioning, and heat pump industry is moving rapidly to address R/R/R concerns. Several R/R/R equipment manufacturers have developed an extensive line of services and equipment to comply with the industry requirements. Cross-contamination of chemicals, reliability of equipment, and purity requirements are items of major concern.

B. FOAM PRODUCTION INDUSTRY

Minimal loss of halocarbons occurs during foam manufacturing (Reference 2). Small amounts of halocarbons are emitted during the foam production process. Most of the foam industry halocarbon emissions are spread out over the life of the foam products, as the chemical is released from the foam cells. These emissions are impossible to recover. Emissions during the manufacturing process can be controlled with carbon absorption technology; however, only a small amount of halocarbon is emitted during manufacturing. Although another option is to recover halocarbons from foam scrap, it is not feasible because of the small amount of scrap generated. The R/R/R technology addressed in this effort is not expected to be a viable alternative for reducing and controlling halocarbon emissions from the foam production industry.

C. AEROSOL AND STERILANTS INDUSTRY

Aerosol alternatives are available; however, the optimal choice varies with the product under consideration. The aerosol industry cannot control halocarbon emissions, other than by using alternative chemicals or nonaerosol systems. Therefore, R/R/R technology is not expected to be a viable alternative for reducing and controlling halocarbon emissions from the aerosol industry.

The sterilant industry has very few alternative technologies available. Alternatives include radiation and use of steam as sterilization techniques. There are also expensive add-on engineering systems available for recycling the CFC-12 and ethylene oxide used for sterilization purposes. The technology is expensive and much different from that being evaluated in this effort (Reference 2).

D. SOLVENT INDUSTRY

Solvent losses can be reduced using solvent recovery systems that consist of enclosed cleaning stations, vapor collection systems, carbon adsorption technology, and improved handling techniques. The industry estimates that typical plant facilities lose 80 to 90 percent of recoverable halocarbons, but this trend is changing (Reference 2). Alternative substitutes such as aqueous cleaning, solvent emulsions, terpene cleaning, and HCFC-based cleaners are available and under evaluation by numerous industry organizations. "How clean is clean?" "Does it meet specifications?" These are the primary questions that must be addressed before alternative cleaning substitutes are deemed acceptable. R/R/R technology includes carbon adsorption technology, distillation units, and filtering equipment. The efficiency of filtering equipment is, however, limited by the high contaminant loading of used halocarbon solvents. Some of the equipment evaluated in this survey may possibly be used to recover/recycle/reclaim used solvents; however, the halocarbon solvent use sector has equipment requirements different from the refrigeration and fire protection sectors, which are the focus of this study.

E. FIRE PROTECTION INDUSTRY

Little work has been performed on halon impurities and needed purity levels. Some work is presented in References 16, 18, and 19. No impacts have been reported on fire suppression effectiveness attributable to impurities; however, the presence of impurities could degrade delivery systems and system performance. Corrosion from hydrohalic acids could lead to vessel failure or system degradation. This has been observed in a few cases with Halon 1211 portable extinguishers, where both tanks and dip tubes had been badly damaged. High particulate loading and oils could clog discharge orifices.

Nitrogen and other noncondensable gases present a major problem in halon systems since venting of the pressure head or removal of dissolved gases is difficult without halocarbon loss. Nitrogen is readily soluble in Halon 1301. Nitrogen is introduced into halons by pressurization of suppression systems (most, but not all, Halon 1301 systems are nitrogen-pressurized) or when used to facilitate transfers. The effect of dissolved nitrogen on system performance must be assessed; however, the presence of nitrogen is expected to cause no problems once the halon is installed. On the other hand, the presence of dissolved nitrogen places pressure constraints on vessels and components in R/R/R systems. It may be best to transfer both nitrogen and Halon 1301 and not attempt separation, though this procedure must be carefully assessed. Other noncondensable dry gases (oxygen and argon) can be introduced in small amounts during handling and in larger amounts by using air to effect transfers. Note that the use of air pressurization for transfer is, however, not a recommended practice since moisture may also be introduced.

An important consideration for firefighting effectiveness is to prevent accidental introduction of other halocarbons into Halon 1301, 1211, or 2402 containers, thereby recharging extinguishing systems with a less effective or even an ineffective agent. If halon R/R/R equipment reduces contaminants to new-agent specifications, the firefighting effectiveness is the same as that for a newly manufactured agent. The type and amount of contaminants expected in the recovered agent should be identified, and the effect of each possible contaminant on firefighting effectiveness must be evaluated.

F. SAFETY

The greatest safety issues are the toxicities of the pure compounds and the contamination degradation products from exposure caused by pressure vessel and piping rupture and by other component failures when servicing halocarbon systems. In particular, the purity requirements and the effects of contaminants on pressure vessels and the pressure vessel codes must be addressed.

The toxicity of hydrogen halides, which are probable contaminants from hydrolysis, is well documented, though the risk must be assessed. Degradation of halocarbons can also occur through oxidation, reaction with metals, and thermal decomposition. In addition to hydrogen halides, degradation products could include carbonyl dihalides, fluoroformic acid, products of coupling reactions (e.g., perfluoroethane), and alkenes (e.g., tetrafluoroethylene). Carbonyl dihalides and fluorinated alkenes are acutely toxic. For some halons, free bromine can be generated by what is apparently a photocatalytic oxidation. Plasticizers, some of which are toxic, can be extracted from polymers by halocarbons. The actual expected contaminant exposure levels for personnel present during R/R/R processes must be carefully assessed to determine safety problems. Although many of these degradation (contaminant) materials are acutely toxic, exposures may represent insignificant risks resulting from low exposure levels and short contact times. Safety and exposure concerns are especially important when handling materials associated with large systems.

Oils and particulates are unlikely to cause direct health problems by inhalation; however, particulate matter from equipment failures could cause injury during chemical expulsion. Some concern exists about injury to personnel directly exposed to halocarbons from filings and other particulates occasionally found in system piping.

G. RESIDUES

Oil and particulates from expelled fire extinguishants can cause residue problems. In a few cases, serious damage to computer and electronic facilities has been attributed to extinguishing agent contamination. One example was the severe damage, which resulted in a law suit, from discharge of oil-contaminated HCFC-22 during test of a Halon 1301 system at a Denver Bank. Other cases have occurred. Contaminants could degrade critical electrical and mechanical systems, leading to system failure. Thus, the effect of contaminants on critical components following discharge of halocarbons must be assessed.

H. QUALITY ASSURANCE

The issues of quality assurance and quality control (QA/QC) will become increasingly important as the existing banks of halocarbons are reduced. Several methods are available for assessing contamination. Acidity evaluations can be used to determine hydrofluoric acid (which may be missed by chloride ion tests) and organic acids from oxidation of lubricants. Gas chromatography (GC) and gas chromatography mass spectrometry (GC/MS) are relatively new methods for assessing halon purity. Nuclear magnetic resonance (NMR) spectrometry has also been shown to be useful. Although these instrumental methods for identifying and quantifying halocarbon contaminants are available at most fully equipped laboratory facilities, they are expensive, time-consuming, and generally not practical when handling small volumes of material. Simple indicators are available for detection of moisture and oil contamination and for visual inspection. Contamination with moisture is the major problem, provided that problems associated with compressor and pump oil have been solved.

At least one simple test kit that gives determinations of moisture and acid contamination is now marketed through Carrier Corporation distributors. This test device is attached to a vapor port of the system or storage container and is allowed to remain for 10 minutes. Color changes inside the glass tube indicate normal, low, medium, or high moisture content and unacceptable acid content. The quantitative meaning of these indications is not specified in the brochure describing the test kit. This kit is primarily intended to detect levels of moisture or acids in a refrigeration or air conditioning system that might cause premature breakdown if not corrected. However, the kit could also be used in the field to detect gross contamination of recovered halocarbons to influence decisions on the appropriate recycle or reclamation technique.

Moisture causes halocarbon decomposition and formation of acids, which can corrode equipment. As purchased, halocarbons generally have a maximum specified moisture content of 20 ppm and usually contain 6 to 10 ppm. Moisture is introduced into the halocarbon in several ways: servicing operations, use under humid conditions, not removing moist air from systems that have been allowed to remain open in contact with the atmosphere, and not drying systems completely after hydrostatic testing.

Concerns about contamination of halocarbons with other halons, halon alternatives, CFCs, and CFC alternatives will increase as recycling of these related compounds from existing banks becomes more common. QA/QC procedures must be developed to assure that materials are not mixed during recovery and storage. QA/QC procedures for the recycling levels outlined above should be developed and presented in terms of cost, applicability, and potential for contamination. Parameter limits and specifications for recycled CFC-12 have been defined by SAE, ARI, and UL standards (Section VI). The important criteria are assessment of moisture, oil, particulates, hydrogen halides, free halogen, and organic decomposition products. QA/QC procedures that are developed must be applicable to the halocarbon alternatives.

Contamination from handling and long-term storage must also be evaluated. The determination of possible quality problems associated with halocarbon banks begins with the identification of storage tank materials, their exterior environments (temperature, moisture, and installation area), and connection fitting requirements for R/R/R equipment. Since a major cause of contamination is human error, reliability of the personnel handling halocarbons is a major concern. Halocarbons are subjected to various environments: high temperatures (enclosed compartments, engine nacelles, roof tops, etc.); low temperatures (northern winters, aircraft cargo bays, etc.); and temporary storage containers used by system installers and manufacturers. Different halocarbon handling techniques are associated with each system; however, provided moisture contamination has been prevented or minimized, the metals and alloys used in system and storage components are not expected to pose a significant problem. Nevertheless, differences in contaminants from metal alloys and other materials must be evaluated. Compatibility with component materials of handling equipment must also be considered since halocarbons can act as solvents. These QA/QC issues should be addressed before developing a USAF full-scale recovery, recycling, and reclamation program.

SECTION VI
HALOCARBON REGULATIONS, STANDARDS, SPECIFICATIONS, AND GUIDELINES

Few regulations, standards, specifications, and guidelines for halocarbon R/R/R processes and purity requirements already exist. Many professional societies, institutes, and organizations are developing standards to meet the needs imposed by the Montreal Protocol and to limit emissions of halocarbons. Many other standards and specifications throughout the DoD and industry may be affected by R/R/R decisions.

A. AIR-CONDITIONING AND REFRIGERATION INSTITUTE

The Air-Conditioning and Refrigeration Institute (ARI) has released ARI Standard 700-88, "Specification for Fluorocarbon Refrigerants," which specifies the physical properties of fluorocarbon refrigerants and defines acceptable levels of quality for new, reclaimed, or repackaged refrigerants used in air-conditioning and refrigeration products (Reference 20). Allowable contaminants specified in this standard are essentially the same as those for new refrigerants. ARI has just released ARI Guideline 1990, "Containers for Recovered Fluorocarbon Refrigerants," which presents good practices for the use of cylinders for receipt, storage, and transportation of used, recovered refrigerant (Reference 17). The Chemical Section of ARI is also developing a standard to measure the performance of R/R/R equipment for the stationary refrigeration and air-conditioning industry.

B. AMERICAN SOCIETY OF HEATING, REFRIGERATING, AND AIR-CONDITIONING ENGINEERS

The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) has recently published a guideline "Reducing Emissions of Fully Halogenated Chlorofluorocarbon (CFC) Refrigerants in Refrigeration and Air-Conditioning Equipment and Applications," which cover all refrigeration and air-conditioning equipment and systems that use fully halogenated CFC refrigerants (Reference 21).

C. SOCIETY OF AUTOMOTIVE ENGINEERS

The Society of Automotive Engineers (SAE) has published two recommended practices and one standard on R/R/R of refrigerants. These were developed in a cooperative project between the EPA and several automotive industry professional societies and associations. SAE

J1989, issued in October 1989, provides recommended practice and service guidelines for technicians when repairing vehicles and operating equipment for the R/R/R of mobile automotive air-conditioning systems (Reference 22). SAE J1990, also issued in October 1989, provides equipment specifications for CFC-12 R/R/R systems used to service automobiles, light trucks, and other vehicles with similar CFC-12 systems (hermetically sealed systems are not covered) (Reference 23). SAE J1991 is a standard issued in October 1989 that establishes minimum levels of purity for CFC-12 removed from mobile automotive air-conditioning systems prior to reuse in the same or similar system(s) (Reference 24). The contaminants covered and specified by this standard are limited to moisture, refrigerant oil, and noncondensable gases.

D. UNDERWRITERS LABORATORIES

The Underwriters Laboratories (UL) has developed a safety and performance standard (UL 1963) that is primarily for CFC-12 mobile air conditioning R/R/R equipment (Reference 25). UL 1963 specifies requirements for R/R/R equipment in accordance with the National Electric Code of the National Fire Protection Association (NFPA) 70 (Reference 26). The standard evaluates automotive refrigerant R/R/R equipment for adequacy in recovering and recycling R-12. The standard defines what constitutes a standard contaminated sample, a high-moisture contaminated sample, and a high-oil contaminated sample for R-12. It then specifies the method and sequence for recycling refrigerant samples through R/R/R equipment and the maximum levels of contaminants that are acceptable in the recycled CFC-12. Test methods for determining contaminant levels are also specified.

Underwriters Laboratories is also developing a standard for R/R/R equipment for Halon 1211. An ad hoc committee of industry representatives has been formed, and an initial draft of the proposed standard, UL 2006, has been prepared (Reference 27). The current schedule calls for release of the draft of UL 2006 for industry review and comment not later than 1 July 1990. Equipment and performance requirements will be similar to those outlined under UL 1963.

E. ENVIRONMENTAL PROTECTION AGENCY ADVANCE NOTICE OF PROPOSED RULE-MAKING ON CHLOROFLUOROCARBON RECYCLING

The Environmental Protection Agency (EPA) released an Advance Notice of Proposed Rule-Making (ANPRM) on Chlorofluorocarbon Recycling on 1 May 1990. The purpose of this ANPRM is to solicit comments on issues needed by EPA in developing a national recycling program that would encourage or require recycling of ozone-depleting compounds. Written comments on this ANPRM were required to be submitted to the EPA by 2 July 1990. The full text of the ANPRM (Reference 8) is available from the Bureau of National Affairs, Inc., Washington, DC 20037. The following is a synopsis of key issues in the ANPRM.

The goal of EPA is to focus on halocarbon end uses in which significant recovery, recycling, and reclamation are already technically and economically feasible. EPA estimates that one-third of all CFCs could be recycled by the year 2000. Requirements for recovery, recycling, reclamation, and reuse of halons and CFCs that are both technologically and environmentally sound will be evaluated. Possible regulatory and nonregulatory programs that promote or ensure efficient recovery and recycling will be considered. The approach includes examination of the extent to which recycling and reclamation provide environmental and economic benefits, the extent to which market inefficiencies impede the marketplace from developing an effective recycling program, and the appropriate regulatory scheme should federal regulation be necessary.

EPA states that if it were to choose the regulatory approach, the first priority would be to target the mobile air-conditioning and stationary refrigeration and air-conditioning industry, because of the amount of emissions recoverable, the advancement of technology in this industry, and the petition from the Alliance for a Responsible CFC Policy (a trade organization of companies involved in the CFC industry) asking for uniform federal regulations for CFC conservation and recycling standards. The regulations would build on efforts underway by the private sector and state and local regulatory agencies.

EPA requested comments on national recycling program development issues in the following four areas:

1. Market-Based Program

This program is a deposit/refund system where a deposit would be added to the purchase price of the controlled substance at the appropriate point of sale. The deposit would be refunded to persons or firms that returned used controlled substances to designated collection points.

2. Direct Regulations

These regulations mandate recycling in end-use sectors where recycling is most feasible as determined by available technology and cost relative to reduction in controlled substance use. Regulations would probably first target the mobile air-conditioning and stationary air-conditioning and refrigerating sectors. Compliance monitoring might involve limiting the sale of controlled substances to commercial users or vendors who would be required to purchase recycling equipment and possibly, in conjunction, a requirement that all service technicians be certified.

In addition, a requirement is being considered as a part of a mandatory recycling program that all recovery/recycling equipment be certified by Underwriters Laboratory or an equivalent certifying laboratory to meet the minimum standard of purity for the intended use. The sale and use of equipment not certified to clean the chemical to an acceptable level of purity may be banned.

3. State and Federal Roles

EPA is investigating whether the compliance and enforcement for a mandatory recycling program should be a federal, state, or joint program.

4. Preemption of State and Local Regulations

EPA is investigating the extent to which a mandatory recycling program would preempt state and local regulations controlling the use and emissions of CFCs and halons.

The time schedule being considered by EPA for mandatory recycling of CFCs in mobile air conditioners prohibits unnecessary venting of CFCs during manufacture, leak detection, system recharge, and service repairs by 1 January 1992. A two-stage approach is being considered. The first stage would require larger shops to recycle CFCs by an early date. Smaller shops would follow within one year.

For halons, EPA is requesting comments on the technical and economic feasibility of requiring 99 percent recovery of Halon 1211 during cylinder maintenance, recharging, or tear-down by 1 January 1991, and the feasibility of 99 percent recovery of Halon 1301 by 1 January 1992.

The ANPRM addresses the recycling of presently used CFCs and halons. As new compounds are substituted and come into use, EPA is considering broadening any recycling program to include HCFC alternatives and other compounds known to deplete the ozone layer (i.e., methyl chloroform, carbon tetrachloride, etc.).

F. MILITARY SPECIFICATIONS AND STANDARDS

The USAF and all the military departments are large users of CFCs and halons. Consequently, there are many military specifications and standards that either directly relate to requirements for CFCs and halons or reference other specifications that require CFCs and halons. The DoD has conducted a study, in conjunction with EPA, to identify all of the MILSPECS and MILSTDS written by the DoD or other federal agencies or adopted by private industry that directly or indirectly require the use of CFCs, halons, or chlorinated solvents. The results of this preliminary work identified over 300 MILSPECS and MILSTDS that are directly related to the DoD use of CFCs and halons.

Most of these MILSPECS and MILSTDS will probably require modifications as CFCs and halons become short in supply, as alternative compounds become available, and as CFCs and halons are recovered and recycled for reuse. In some applications, purity requirements may preclude the use of recycled compounds if "new" compound purity cannot be achieved.

SECTION VII
CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

Commercially available equipment and services have been identified in this study for the recovery, recycling, and reclamation of used halocarbons in the refrigeration, air-conditioning, heat pump, and halon fire protection use sectors. R/R/R equipment for rigid and flexible foam, electronic component cleaning, and metal degreasing, aerosol, sterilant, and other miscellaneous use sectors were not evaluated, as they were beyond the scope of this effort. Characteristics of available equipment have been collected and put into tabular form for ease of comparison. Many factors influence the decision on which unit is appropriate for specific R/R/R tasks. The requirements have to be identified before the evaluation selection process can begin. Capabilities and specifications for the equipment included in this study have been reported as received from the manufacturers. It is not within the scope of this survey to verify the validity of the manufacturers' data and claims.

Most of the recovery/recycling equipment available is targeted for CFCs in the mobile air-conditioning and stationary refrigeration and air-conditioning equipment market. EPA is considering rules to make it mandatory that R/R/R equipment be certified by an independent laboratory. Those already certified by UL are noted in Table C-1. Very little equipment is presently available specifically for R/R/R of halons.

Concerns and issues related to the R/R/R of halocarbons were identified and discussed. The key issues are related to identification of acceptable purity and quality assurance requirements of recycled halocarbons. The resolution of these issues will require extensive study and testing throughout the industry.

B. RECOMMENDATIONS

Recovery, recycling, and reclamation requirements for reduction of halocarbon emissions have far-reaching implications for all organizations, including the USAF. The traditional procedures involving CFCs as cooling and cleaning fluids and halons as fire-extinguishing agents will require significant changes. The following are recommendations that will provide inputs to the ultimate decisions on a USAF halocarbon R/R/R program.

1. Institute pilot programs for R/R/R of CFCs and halons to provide experience and data for future decision points.

2. Determine the purity requirements for recovered and recycled halocarbons. The purity requirements will dictate whether recycling equipment will be sufficient or the use of a bulk reclamation facility will be necessary.

3. Determine the impact of various halocarbon recycling requirement programs being considered by the EPA ANPRM, whether voluntary or regulatory.

4. Determine the impact of any halocarbon recycling program on the many military specifications and standards that currently specify halocarbons. This should include an evaluation of processes that may not be appropriate for use of recycled halocarbons because of purity requirements.

5. Determine the cost and funding requirements for implementing a USAF halocarbon recycling program. Answers to the above four recommendations are required to define the cost question.

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APPENDIX A

HALOCARBON/HALON RECOVERY/RECYCLING/RECLAMATION MANUFACTURERS AND SERVICES

List of CFC/Halon Recovery/Recycle/Reclamation

Manufacturers and Services

(Alphabetical by Company Name)

June 1990

Amerex Corp
P.O. Box 81
Trussville, AL 35173-0081
205-655-3271
Paul Huston

Appliance Recycling of America, Inc.
654 University Ave.
St. Paul, MN 55104
612-378-1100
Katy Boone

Applied Ecological Systems
P.O. Box 697
Hazelhurst, GA 31539
800-282-7679
L. A. Goddard

Carrier Corp.
Box 4808
Syracuse, NY 13221
315-432-7405
Doug Rector

Cerberus Pyrotronics
8 Ridgedale Ave.
Cedar Knolls, NJ 07927
201-397-7139
Richard J. Pierce

C-K Industries, Inc.
P.O. Box 7
Fresno, TX 77545
713-431-0664
Jerry Konnaughton

Davco Manufacturing Company
3601 Glover Road (Forks Township)
Easton, PA 18042
215-559-1400
Richard Walker

Du Pont Freon Products Div.
Building B-13226
Wilmington, DE 19898
302-773-6887
Charles A. McCain

Ener Craft, Inc.
5117 E. 1st St.
Austin, TX 78702
512-385-3444
Ray Coker

Everco Industries, Inc.
6565 Wells P.O. Box 7224
St. Louis, MO 63177
800-323-5473
Roger Lashley

Fenteck, Inc.
One Walnut Lane
Selbyville, DE 19975
302-436-1780
David C. Grant

Frick Co. Blu-Cold Division
345 W. Main St.
Waynesboro, PA 17268-1496
717-762-2121
Al Reimers

Getz Manufacturing
1723 S.W. Adams
Peoria, IL 61602-9990
309-674-1723
Kevin Redenhour

Gill-Fam Manufacturing, Inc.
804 Development Dr.
Kingston, Ontario K7M 5V7, CANADA
613-384-0150
Ken Gill

Great Lakes Chemical Corp.
P.O. Box 2200
Lafayette, IN 47906
317-497-6270
Al Thornton

High Frequency Products
P.O. Box 380016
Miami, FL 33238
213-450-4941
Carl Gettleman

IG-LO, Inc.
P.O. Box 391
Hernando, MS 38632
601-429-4471
Bob Williams

Industrial Chiller Services
4317 FM-2351
Friendswood, TX 77546
713-482-6082
Ed Chaney

Intermark Environmental Science
110 W. Arroyo St.
Reno, NV 85509
702-322-6769
Paul Valls

JameskamM Technologies
4730 W. Bancroft
Toledo, OH 43615
419-531-3313
James Kamm

Limco Manufacturing Corp.
1 Garvies Point Rd.
Glen Cove, NY 11542
516-671-7400
Abe Wasserstrom

MDI
6285 West 48th Ave.
Wheat Ridge, CO 80033
303-423-1391
Jack Major

Murray Corporation
Schilling Circle
Cockeysville, MD 21030
301-771-0380
Arthur Hobbs

National Refrigerants, Inc.
Hickory Pointe, 2250 Hickory Rd.
Plymouth Meeting, PA 19462
215-834-0200
Colin Dayton

Omega Recovery Services
12504 E. Whittier Blvd.
Whittier, CA 90602
213-698-0991
Lorraine Segala

Production Control Units, Inc.
2282 W. Dorothy Lane
Dayton, OH 45439
513-299-5597
Gary Marshall

Quadrex HPS, Inc.
1940 N.W. 67th Place
Gainesville, FL 32606
904-373-6066
Tech. Dept.

Recylene Products, Inc.
405 Eccles Ave So.
San Francisco, CA 94080
415-822-4949
Technical Department

Refrigerant Reclamation Systems
Route 15, Box 128
Mechanicsville, VA 23111
804-746-3231
Dan Watson

Refrigerant Recovery Systems, Inc.
Route 15, Box 128
Tampa, FL 33673
813-237-1266
Wayne Taylor

Refrigerant Technologies, Inc.
1380 Spahn Ave.
York, PA 17403
717-845-1300
Peter Richichi

Robinair Division Sealed Power Corporation
9 Robinair Way
Montpelier, OH 43543-0193
419-485-5561
George Maes

Rolo Recovery and Recycling Corp.
5732 Phillips Highway
Jacksonville, FL 32216
904-731-0022
Roy McGriff, Jr.

Serv-I-Quip, Inc.
127 Wallace Ave
Downing Town, PA 19335
215-873-7010
Mike Richey

Technical Chemical Co.
10737 Spangler
Dallas, TX 75220
214-556-1421
Dianne Schwartz

Tegra Tek
4886 Fractory Dr.
Fairfield, OH 45014
513-829-3888
Tom Mohring

ThermaFlo
3640 Main St.
Springfield, MA 01107
412-733-4433
Mike Fioretti

Thermal Engineering Co.
2022 Adams St.
Toledo, OH 43624
419-244-7781
Victoria M. Kamm

The Trane Co.
3600 Parmmel Creek Rd.
La Crosse, WI 54601
608-787-3857
Bob Roth

Tuthill Pump Co.
5143 Port Chicago Hwy.
Concord, CA 94520
415-676-8000
Charlie Kanturek

Tritop, Inc.
495 19th Ave.
Lachine, Quebec H8S 3R9, CANADA
514-634-7031
Len BourJeouis

Van Hook Service Co. Inc
769 Emerson St.
Rochester, NY 14613
716-254-4375
Technical Department

Van Steenburgh Engineering Laboratories
1900 South Quince St., Unit G
Denver, CO 80231
303-696-0113
Jim Murlin

White Industries
9210 Castlegate Dr.
Indianapolis, IN 46256
317-849-6830
John Hancock

Wynn's Climate Systems, Inc.
1900 S.E. Loop 820, P.O. Box 40870
Fort Worth, TX 76140
817-293-4600
Jeff Humphrey

APPENDIX B

MARKET SURVEY LETTER

«date»

«name»
«company»
«street»
«city», «state» «zip»

Re: CFC and Halon Recovery and Recycle Equipment Market Study

Dear «name»:

Our organization is performing a Market Study Investigation for HQ Air Force Engineering and Services Center of the potential sources for halocarbon (chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), halons, etc.) handling and recycling equipment systems or services. Your name and organization was given to me by Jean Lupinacci at EPA Washington, D.C. or from various other inquires within the industry. Please, provide to us the following information on your organizations product(s) by May 30, 1990, in order to be included in our analysis of the current available halocarbon recovery, recycle, or handling equipment or services on the market.

The equipment should be capable of meeting the following requirements: 1) Recover and recycle halocarbons including but not limited to refrigerants R-11, R-12, R-22, R-113, R-114, R-115, R-500, R-502, and Halons 1011, 1211, 2402, and 1301; 2) recover and recharge halocarbons for refrigeration, air conditioning, and halons for fire suppression systems; 3) remove contaminants and purify the halocarbons to a condition suitable for reuse; 4) give quantifiable measurements of the quality of the recycled halocarbon product; 5) must be usable by trained technicians at the field level; 6) ensure and indicate that the halocarbon being handled cannot escape to the atmosphere; 7) operate with halocarbons in liquid or gaseous states.

If your firm is capable of furnishing equipment or information which meets the above requirements, <u>in-part or total</u>, please submit technical information and catalog data to the following address:

Ted A. Moore
New Mexico Engineering Research Institute
Center for Global Environmental Technologies
2650 Yale SE
Albuquerque, New Mexico 87106

The data should include current pricing information, availability schedules, and technical and other information which will show ability to meet the above requirements. Operation, maintenance, and repair manuals would also be acceptable. The equipment limitations must be clearly stated as part of all responses. This request is for informational and planning purposes only. The government does not intend to award a contract on the basis of this letter or to otherwise pay for the information provided. If the government develops a future need for the item described herein, sources responding to this letter with adequate information indicating the capability to meet the requirements stated above will be among those solicited.

The technical documentation resulting from this effort will be made publicly available through the National Technical Information Service (NTIS), selected journals, and other publications. Personal copies of the final report will, however, be made available to you and your organization in consideration for helping to complete the task. The following information will be provided in the final report, if available at the time of completion:

1) The name, address, and telephone number for vendor.
2) Price, catalog cuts, brochures, and a description of the system explaining the functions of the major components.
3) Data such as discharge and recharge rates, weight, dimensions, compatible halocarbons, and any incompatible halocarbons.
4) A description of how your system can purify the halocarbon. Does it filter, distill, or both? What contaminants can and cannot be removed?
5) Adequacy of operation, maintenance, and repair manuals. Amount of training required for operation. Any vendor training assistance available?
6) Historical information provided by you which could include number of systems in use, names and addresses of users, system age and reliability.
7) An evaluation of all material provided with ratings and recommendations for future considerations.

We recognize that there may not be adequate time for you to respond to our entire request of information. Feel free to provide as much general data as soon as possible. We will consider additional detailed data until such time as the final report is issued. Also, please let me know if your organization is willing to attend and display equipment at a trade show to be organized at a later date.

Thank you very much for considering this request for information. Feel free to contact me concerning any question or comments you may have. I'm sure it will be very helpful to the industry and consumers alike to gain a detailed knowledge of your product(s) and services and their availability on the market.

Sincerely,

Ted A. Moore
Environmental Research Engineer
NMERI/APT
Center for Global Environmental Technologies
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APPENDIX C

RECOVERY/RECYCLING/RECLAMATION EQUIPMENT/SERVICES

EXPLANATION OF TABLES C-1, C-2, AND C-3

Key characteristics of the recovery/recycle equipment and services have been put into tabular form to facilitate comparisons between models or finding equipment given a particular desired characteristic. These tables are constructed in three categories. Table C-1 includes those companies making CFC R/R/R equipment, Table C-2 covers those making halon R/R/R equipment, and Table C-3 includes those companies providing reclamation services for recovered CFCs and halons.

In addition to the company name and the model number of the equipment, 13 other characteristics are contained in the tables. A brief explanation of each characteristic follows.

1. COMPANY--name of the company manufacturing the equipment.

2. MODEL--company model designation.

3. UL LISTED--an indication that the equipment has been certified by UL testing to meet certain standards. The only UL standard for recycling halocarbons that currently exists is UL 1963, which covers only CFC-12 automotive recovery and recycling equipment. UL 2006 for Halon 1211 is under development. UL recycling equipment standards for other halocarbons do not yet exist. Furthermore, EPA has announced in an Advanced Notice of Proposed Rule Making (ANPRM) (see discussion in Section VI, E) that if a mandatory recycling program is instituted, they may ban the sale and use of equipment not certified to clean the chemical to an acceptable level of purity. The certification would be required from Underwriters Laboratory or an equivalent certification organization.

4. CFC (or HALON) PROCESSED--the halocarbon(s) indicated by the manufacturer that the equipment would recover/recycle.

5. PROCESS PERFORMED--an indication of what the equipment was designed to do - recover only or recover and recycle.

6. METHOD OF PURIFYING--the method used for removal of contaminants from recovered used halocarbons.

7. CONTAMINANTS REMOVED--list of contaminants that the manufacturer stated could be reduced through the recovery/recycling process.

8. INDICATION OF PURITY LEVEL--what the equipment has for visual indication of purity from various contaminants.

9. RATE OF RECOVERY (LBS/MIN)--the recovery/recycle rate of the equipment in pounds per minute. This factor varies considerably depending on temperature, pressure, suction head, vapor or liquid, etc. Single values are reported by some manufacturers while ranges are provided by others. The company should be contacted to determine the rate for the exact conditions.

10. INTERNAL STORAGE CAPACITY (LBS)--this indicates the capability of the equipment to store halocarbons in a built-in container. Some manufacturers provide reusable recovery/storage containers with the unit included in the basic price, while others have them as extra cost options.

11. PHYSICAL SIZE (W x D x H, IN)--the external dimensions of the equipment in inches, width by depth by height.

12. WEIGHT (LBS)/PORTABILITY--the weight of the unit in pounds and an indication of how it is designed to be moved if portable, i.e. handle(s), casters, wheeled dolly, etc.

13. UNITS IN SERVICE--the number of units that have been manufactured and are in use. This number was not provided by some manufacturers and was only estimated by others.

14. COST--the cost of the unit. The costs reported vary from wholesale to retail. Approximations are provided for some units. Volume discounts are available for many units. These values should be used only for rough comparisons. The manufacturer should be contacted for exact costs to fit specific situations.

15. AVAILABILITY--an indication of whether the units are in stock, in production, a delivery delay can be expected, etc., at the time of this study. The manufacturer should be contacted for exact delivery quotation.

TABLE C-1. CFC RECOVERY/RECYCLING/RECLAMATION EQUIPMENT.

COMPANY	APPLIED ECOLOGICAL SYSTEMS	APPLIED ECOLOGICAL SYSTEMS	APPLIED ECOLOGICAL SYSTEMS	CARRIER CORP.	CARRIER CORP.
MODEL	RetrieverTM R-2.2	R-2.4	R-30	RMS 19QQA02	RMS 19QQA40
U.L. LISTED	No	No	No	No	No
HALOCARBONS PROCESSED	12, 22, 500, 502, 134a	12, 22, 500, 502, 134a	Custom-made units per customers requirements. Built for large refrigeration and AC systems (200 lbs and up).	11, 113, 123	11, 113, 123
PROCESS PERFORMED	Recovery, Recycle	Recovery, Recycle		Recovery, Recycle	Recovery, Recycle
METHOD OF PURIFYING	Filters, Oil trap	Filters, Oil traps		Distillation, Filter Drier	Distillation, Filter Drier
CONTAMINANTS REMOVED	Particulates, Oils, Acids, Moisture	Particulates, Oils, Acids, Moisture		Oil (<1000 ppm) Water (<50 ppm) Acids and Particulates	Oil (<1000 ppm) Water (<50 ppm) Acids and Particulates
INDICATION OF PURITY LEVEL	Sight Glass Indicates Filter Needs Change	Sight Glass Indicates Filter Needs Change		None	None
RECOVERY RATE (LB/MIN)	1.5	2.5		N/A	N/A
PHYSICAL SIZE (W*D*H, IN)	12*21*12	13*24*12		29*52*45	29*102*45
INTERNAL STORAGE CAPACITY (LB)	8	12		1600	3300
WEIGHT (LBS)	54	60		505	820
PORTABILITY	Handle	Handle		Crane and Fork Lift Holes	Caster Kit Available
UNITS IN SERVICE	Approx. 350 Since 1980	Approx. 350 Since 1980		Approx. 40	Approx. 40
COST (PER UNIT)	$1115	$1316		$6000	$12,000
AVAILABILITY	6 to 8 Weeks	6 to 8 Weeks		In Production	In Production

TABLE C-1. CFC RECOVERY/RECYCLING/RECLAMATION EQUIPMENT (CONTINUED).

COMPANY	DAVCO MANUFACTURING COMPANY	DAVCO MANUFACTURING COMPANY	ENER CRAFT, INC.	EVERCO INDUSTRIES, INC.	GILL-FAM MANUFACTURING
MODEL	DM-275	DM-285	SSL 2101	A9950	CFC-TEK 2000
U.L. LISTED	No	No	No	Yes	No
HALOCARBONS PROCESSED	All (Pressures up to 400 lb/in.2)	All (Pressures up to 400 lb/in.2)	12, 22, 500, 502	12, 22, 500, 502	11, 12, 22, 113, 114, 500, 502
PROCESS PERFORMED	Recovery, Liquid Only	Recovery, Mixed Vapor and Liquid	Recovery, Recycle	Recovery, Recycle	Recovery, Recycle
METHOD OF PURFYING	N/A[a]	N/A	Patented Distillation Filter Process	Filtration, Auto Air Purge	Filter/Drier
CONTAMINANTS REMOVED	N/A	N/A	Acids, Moisture, Oils, Particulates, Noncondensables	Acids, Moisture, Oils, Particulates	Acids, Moisture, Oils, Particulates
INDICATION OF PURITY LEVEL	b	b	None (Tested Recycled CFC has Met ARI 700-88)	Moisture Sight Glass	Moisture Sight Glass
RECOVERY RATE (LB/MIN)	30	1.5	2 to 7	0.5 Recovery, 2 Recycle	2 to 3
PHYSICAL SIZE (W*D*H, IN)	12*28*11	15*18*13	27*34*46	20*21*41	26*21*46
INTERNAL STORAGE CAPACITY (LB)	None	None	None	None	5
WEIGHT (LBS)	95	70	250	146	140
PORTABILITY	2 Handles	2 Handles	Casters	2-Wheel Dolly	2-Wheel Dolly
UNITS IN SERVICE	12 (Over the Last 7 Years)	In Early Production	Approx. 10	900	None
COST (PER UNIT)	$6499	$2499	$17,493	$3299	$4300
AVAILABILITY	Stock to 60 Days	Stock to 60 Days	Approx. 3 Weeks	In Stock	3 to 4 Weeks

TABLE C-1. CFC RECOVERY/RECYCLING/RECLAMATION EQUIPMENT (CONTINUED).

COMPANY	GILL-FAM MANUFACTURING	GILL-FAM MANUFACTURING	HIGH FREQUENCY PRODUCTS, INC.	IG-LO, INC.	INTERMARK ENVIRONMENTAL SCIENCES, INC.
MODEL	CFC-TEK 2002	CFC-TEK 2003	"Ozone Protector" ACR-1	IG-LO/DRAF 1400	ECOTEK
U.L. LISTED	No	No	No	Yes	No
HALOCARBONS PROCESSED	11, 12, 22, 113, 114, 500, 502	11, 113, 114	12, 22, 500, 502	12	12, 22, 500, 502
PROCESS PERFORMED	Recovery, Recycle	Recovery, Recycle	Recovery, Recycle	Recovery, Recycle	Recovery, Recycle
METHOD OF PURFYING	Filter/Drier	Filter/Drier	Filters, Distillation (Vapor and Liquid)	Filter/Driers, Oil Distiller	5-Stage, Single Pass Filter/Drier
CONTAMINANTS REMOVED	Acids, Moisture, Oils, Particulates	Acids, Moisture, Oils, Particulates	Acids, Moisture, Oils, Particulates	Acids, Moisture, Oils, Particulates Noncondensable Gases	Acids, Moisture, Oils, Particulates
INDICATION OF PURITY LEVEL	Moisture Sight Glass	Moisture Sight Glass	Moisture Sight Glass	Moisture Sight Glass	Moisture Sight Glass
RECOVERY RATE (LB/MIN)	1	0.5	1 to 2	3	3 to 5 Recovery, 0.5 Recycle
PHYSICAL SIZE (W*D*H, IN)	22*21*46	26*21*46	14*10*12	26*22*42	21*24*45
INTERNAL STORAGE CAPACITY (LB)	2.5	None	None	9.5	50
WEIGHT (LBS)	70	165	40	145	150
PORTABILITY	2-Wheel Dolly	2-Wheel Dolly	Handle	2-Wheel Dolly	Casters
UNITS IN SERVICE	None	None	Prototype	Early Production	In Testing
COST (PER UNIT)	$3000	$4650	---	$2500	$4490
AVAILABILITY	3 to 4 Weeks	3 to 4 Weeks		4 Weeks	Soon

TABLE C-1. CFC RECOVERY/RECYCLING/RECLAMATION EQUIPMENT (CONTINUED).

COMPANY	JAMES KAMM TECHNOLOGIES	MAJOR DIVERSITIES INC.	MAJOR DIVERSITIES, INC.	MURRAY CORPORATION	MURRAY CORPORATION
MODEL	"Recovery, II" KATY 3330	"Pinnacle" 1/2 HP	"Pinnacle" 1000 A-B[c]	A.T.C. 5000	A.T.C. 1100
U.L. LISTED	No	No	No	Yes	Yes
HALOCARBONS PROCESSED	12, 22, 500, 502	12, 22, 500, 502	12, 22, 500, 502	12	12
PROCESS PERFORMED	Recovery, Recycle	Recovery, Recycle	Auto A/C Diagnostic & Service with Recovery,/Recycle	Recovery, Recycle	Recovery, Recycle
METHOD OF PURFYING	Filter, Single Pass	Filter/Drier, Distillation Oil Separator	Filters, Single Pass	Filters Single Pass	Filters, Single Pass
CONTAMINANTS REMOVED	95% Removal Part. Acid, Moisture, Oil Separators	Acids, Moisture, Oils, Particulates, Noncondensable	Acids, Moisture, Oils, Particulates, Noncondensables	Acids, Moisture, Oils, Particulates, Noncondensables	Acids, Moisture, Oils, Particulates, Noncondensables
INDICATION OF PURITY LEVEL	Moisture Sight Glass	Moisture Sight Glass	Moisture Sight Glass	Moisture Indicator	Moisture Indicator
RECOVERY RATE (LB/MIN)	2 Vapor 5 Liquid	2 to 4	2 to 4	Not Stated	Not Stated
PHYSICAL SIZE (W*D*H, IN)	16*14*45	13*24*12	A - 13*19*13 B - 13*18*13	36*22*31	26.5*24.5*40
INTERNAL STORAGE CAPACITY (LB)	5	Approx. 12	None	9	24
WEIGHT (LBS)	99	74	A - 32 B - 41	250	200
PORTABILITY	2-Wheel Dolly	Handle	Handle	Casters	Casters
UNITS IN SERVICE	1000	500	24	Thousands	Thousands
COST (PER UNIT)	$1650	$1463	$1540	$6796	$2517
AVAILABILITY	3 Weeks	1 Week	1 Week	In Production	In Production

TABLE C-1. CFC RECOVERY/RECYCLING/RECLAMATION EQUIPMENT (CONTINUED).

COMPANY	NATIONAL REFRIGERANTS, INC.	NATIONAL REFRIGERANTS, INC.	NATIONAL REFRIGERANTS, INC.	PRODUCTION CONTROL UNITS, INC.	PRODUCTION CONTROL UNITS, INC.
MODEL	V1	LV 5	LV 20 Compressed Air Dev.	R-12-PB[d]	R-12-PT[d]
U.L. LISTED	No	No	No	No[e]	No[e]
HALOCARBONS PROCESSED	12, 22, 502	12, 22, 500, 502	12, 22, 500	12	12
PROCESS PERFORMED	Recovery, Vapor Only	Recovery	Recovery	Recovery, Recycle, Vapor Only	Recovery, Recycle, Vapor Only
METHOD OF PURFYING	N/A	N/A	N/A	Filter/Drier, Oil Separator	Filter/Drier, Oil Separator
CONTAMINANTS REMOVED	N/A	N/A	N/A	Acids, Moisture, Oils, Particulates, Noncondensables	Acids, Moisture, Oils, Particulates, Noncondensables
INDICATION OF PURITY LEVEL	N/A	N/A	N/A	None	None
RECOVERY RATE (LB/MIN)	0.5 Vapor	1.5 Vapor 5 Liquid	3 Vapor 20 Liquid	0.3 to 0.5	0.3 to 0.5
PHYSICAL SIZE (W*D*H, IN)	11*21*12	20*22*24	14*31*28	40*40*90	40*40*90
INTERNAL STORAGE CAPACITY (LB)	N/A	N/A	N/A	145	135 (Liq. Transfer Pump)
WEIGHT (LBS)	30	135	85	800	800
PORTABILITY	Handle	2-Wheel Dolly	Handle	4 Casters	4 Casters
UNITS IN SERVICE	8	2	6	7	32
COST (PER UNIT)	$1000	$5000	$4000	$18,000	$18,000
AVAILABILITY	3 to 4 Weeks	3 to 4 Weeks	3 to 4 Weeks	10 Weeks	10 Weeks

TABLE C-1. CFC RECOVERY/RECYCLING/RECLAMATION EQUIPMENT (CONTINUED).

COMPANY	REFRIGERANT RECOVERY, SYSTEMS, INC.	REFRIGERANT RECOVERY, SYSTEMS, INC.	REFRIGERANT RECOVERY, SYSTEMS, INC.	REFRIGERANT RECOVERY, SYSTEMS, INC.	REFRIGERANT RECOVERY, SYSTEMS, INC.
MODEL	Re-1	ST-11	"Rejuvenator" ST-100	"Rejuvenator" ST-100/A	. "Rejuvenator" ST-1000
U.L. LISTED	No	No	No	Yes	No
HALOCARBONS PROCESSED	12, 22, 500, 502	11, 113	12, 22, 500, 502	12	12, 22, 500, 502
PROCESS PERFORMED	Recovery, Only	Recovery, Recycle	Recovery, Recycle	Recovery, Recycle	Recovery, Recycle
METHOD OF PURFYING	N/A	Distillation, Filter	Distillation, Filter	Distillation, Filter	Distillation, Filter
CONTAMINANTS REMOVED	N/A	Particulates, Acids, Oils, Moisture	Particulates, Acids, Oils, Moisture	Particulates, Acids, Oils, Moisture	Particulates, Acids, Oils, Moisture
INDICATION OF PURITY LEVEL	N/A	None	Moisture Sight Glass	Moisture Sight Glass	None
RECOVERY RATE (LB/MIN)	1 to 2	85 to 120	2 to 3	2 to 3	2 to 6
PHYSICAL SIZE (W*D*H, IN)	18*12*16	60*30*54	18*14*29	32*14*29	18*14*34
INTERNAL STORAGE CAPACITY (LB)	N/A	None	None	50	None
WEIGHT (LBS)	40	550	76	105	130
PORTABILITY	Handle	Casters	Casters	Casters	Casters
UNITS IN SERVICE	Not Provided In Production for 7 Years	Not Provided In Production for 7 Years	Not Provided In Production for 7 Years	Not Provided In Production for 7 Years	Not Provided In Production for 7 Years
COST (PER UNIT)	Suggested List $955	Suggested List $12,500	Suggested List $2498	Suggested List $2438	Suggested List $4998
AVAILABILITY	4 to 6 Weeks	4 to 6 Weeks	4 to 6 Weeks	4 to 6 Weeks	4 to 6 Weeks

TABLE C-1. CFC RECOVERY/RECYCLING/RECLAMATION EQUIPMENT (CONTINUED).

COMPANY	REFRIGERANT TECHNOLOGIES, INC.[f]	REFRIGERANT TECHNOLOGIES, INC.	REFRIGERANT TECHNOLOGIES, INC.	REFRIGERANT TECHNOLOGIES, INC.	ROBINAIR
MODEL	R450	RR750	RRC 1000[g]	RREC 3000[g]	17300
U.L. LISTED	No	Yes	Yes	No	Yes
HALOCARBONS PROCESSED	12	12	12	12	12
PROCESS PERFORMED	Recovery, Only	Recovery, Recycle	Recovery, Recycle	Recovery, Recycle (Vacuum Pump)	Recovery, Recycle
METHOD OF PURFYING	N/A	Distillation, Filter	Filters, Self Clean Unit, Distillation,	Filters, Self Clean Unit, Distillation,	Filter/Drier
CONTAMINANTS REMOVED	Particulates, Acids, Oils, Moisture	Particulates, Acids, Oils, Moisture	Particulates, Acids, Oils, Moisture	Particulates, Acids, Oils, Moisture	Particulates, Acids, Oils, Moisture
INDICATION OF PURITY LEVEL	N/A	Moisture Sight Glass	Moisture Sight Glass	Moisture Sight Glass	Moisture Indicator, Filter Monitor
RECOVERY RATE (LB/MIN)	0.5 to 2.2	0.5 to 2.2	0.5 to 2.2	0.5 to 2.2	0.5 Recovery, 2.5 Recycle (Liq)
PHYSICAL SIZE (W*D*H, IN)	27*32*36	27*32*36	27*32*41	27*32*41	21*20*42
INTERNAL STORAGE CAPACITY (LB)	10	10	10	10	None
WEIGHT (LBS)	Not Provided	130	155	Not Provided	130
PORTABILITY	Not Provided	2-Wheel Dolly	2-Wheel Dolly	Not Provided	2-Wheel Dolly
UNITS IN SERVICE	6 Pre-Production	750	250	None	[h] 2000
COST (PER UNIT)	Not Available	Dealer Net $3564	Dealer Net $5139	Not Available	Suggested Retail $3395
AVAILABILITY	Not in Production	4 to 6 Weeks	4 to 6 Weeks	Not in Production	In Production

TABLE C-1. CFC RECOVERY/RECYCLING/RECLAMATION EQUIPMENT (CONTINUED).

COMPANY	ROBINAIR	ROBINAIR	ROBINAIR	SERV-I-QUIP, INC.	SERV-I-QUIP, INC.
MODEL	17350	17400	17500 B	[1] 0915	[1] 2930
U.L. LISTED	Yes	Yes	Yes	No	No
HALOCARBONS PROCESSED	12	12	12, 22, 500, 502	12, 22, 502	12, 22, 502
PROCESS PERFORMED	Recovery, Recycle	Recovery, Recycle	Recovery, Recycle	Recovery, Recycle	Recovery, Recycle
METHOD OF PURFYING	Filter/Drier, Auto Air Purge	Filter/Drier, Manual Air Purge	Filter/Drier, Manual Air Purge	Filters, Oil Trap	Filters, Oil Trap
CONTAMINANTS REMOVED	Particulates, Acids, Oils, Moisture	Particulates, Acids, Oils, Moisture	Particulates, Acids, Oils, Moisture	Particulates, Acids, Oils, Moisture, Noncondensables	Particulates, Acids, Oils, Moisture, Noncondensables
INDICATION OF PURITY LEVEL	Moisture Indicator Filter Monitor	Moisture Indicator Filter Monitor	Moisture Indicator Filter Monitor	Moisture Sight Glass	Moisture Sight Glass
RECOVERY RATE (LB/MIN)	0.5 Recovery, 2.5 Recycle (Liq)	0.5 Recovery, 0.8 Recycle	1 Recovery, 2.5 Recycle	1 to 3	2 to 6
PHYSICAL SIZE (W*D*H, IN)	23*25*45	21*24*45	23*25*45	72*72*84	72*72*84
INTERNAL STORAGE CAPACITY (LB)	None	None	None	None	None
WEIGHT (LBS)	150	115	165	Approx. 2500	Approx. 2500
PORTABILITY	2-Wheel Dolly	2-Wheel Dolly	2-Wheel Dolly	Nonportable	Nonportable
UNITS IN SERVICE	500	1000	1000	25 to 30	25 to 30
COST (PER UNIT)	$3595	$3095	$4600	$37,230	$46,100
AVAILABILITY	In Production	In Production	In Production	18 to 20 Weeks	18 to 20 Weeks

TABLE C-1. CFC RECOVERY/RECYCLING/RECLAMATION EQUIPMENT (CONTINUED).

COMPANY	SERV-I-QUIP, INC.	TECHNICAL CHEMICAL COMPANY	THERMAFLO	THERMAL ENGINEERING	THERMAL ENGINEERING
MODEL	[1]4950	SERCON 9000	"OZ saver"	6000	7500
U.L. LISTED	No	Yes	No	No	No
HALOCARBONS PROCESSED	12, 22, 502	12, 22, 500,502	12, 22, 500, 502	12, 22, 500, 502	12, 22, 500, 502
PROCESS PERFORMED	Recovery, Recycle	Recovery, Recycle	Recovery and Recharge Only	Recovery, Recycle	Recovery, Only
METHOD OF PURIFYING	Filters, Oil Trap	Filters	N/A	Filters, Oil Trap	Filters Contaminants But Not For Reuse
CONTAMINANTS REMOVED	Particulates, Acids, Oils, Moisture, Noncondensables	Particulates, Acids, Oils, Moisture	N/A	Particulates, Acids, Oils, Moisture	Particulates to Protect Compressor
INDICATION OF PURITY LEVEL	Moisture Sight Glass	Moisture Sight Glass		Moisture Sight Glass	Moisture Sight Glass
RECOVERY RATE (LB/MIN)	4 to 14	2 to 3 Recovery, 6.7 Recycle	1 to 2 Vapor 4 to 5 Liquid	2	0.75
PHYSICAL SIZE (W*D*H, IN)	72*72*84	20*20*48	14*16*36	16*26*20	12*16*17
INTERNAL STORAGE CAPACITY (LB)	None	None	20	None	None
WEIGHT (LBS)	Approx. 2500	150	79	98	73
PORTABILITY	Nonportable	2-Wheel Dolly	2-Wheel Dolly	Casters & Handles	Handle
UNITS IN SERVICE	25 to 30	Approx. 100	Test Units Only	700	Started Delivery May 1990
COST (PER UNIT)	$52,450	$3199	Not Available	$1695	$1232
AVAILABILITY	18 to 20 Weeks	In Stock	Avail. Fall 1990	In Production	In Production

TABLE C-1. CFC RECOVERY/RECYCLING/RECLAMATION EQUIPMENT (CONTINUED).

COMPANY	THERMAL ENGINEERING	THE TRANE COMPANY	THE TRANE COMPANY	THE TRANE COMPANY	VAN STEENBURGH ENGINEERING LABORATORIES
MODEL	8000	RRSA 16	RRSA 34	RRSA 50	LV-30
U.L. LISTED	No	No	No	No	No
HALOCARBONS PROCESSED	12, 22, 500, 502	11, 113, 123	11, 113, 123	11, 113, 123	12, 22, 500, 502
PROCESS PERFORMED	Recovery, Recycle	Recovery, Recycle	Recovery, Recycle	Recovery, Recycle	Recovery, Recycle
METHOD OF PURFYING	Filters, Oil Trap	Filters, Distillation	Filters, Distillation	Filters, Distillation	Filter, Velocity Gradient Separator
CONTAMINANTS REMOVED	Particulates, Acids, Oils, Moisture	Particulates, Acids, Oils, Moisture	Particulates, Acids, Oils, Moisture	Particulates, Acids, Oils, Moisture	Particulates, Acids, Oils, Moisture
INDICATION OF PURITY LEVEL	Moisture Sight Glass	Moisture Sight Glass	Moisture Sight Glass	Moisture Sight Glass	Moisture Sight Glass
RECOVERY RATE (LB/MIN)	2	Not Provided	Not Provided	Not Provided	3
PHYSICAL SIZE (W*D*H, IN)	12*16*22	Not Provided	102*35*73	Not Provided	24*16*41
INTERNAL STORAGE CAPACITY (LB)	None	1800	3400	5000	30
WEIGHT (LBS)	120	1800	2000	2300	200
PORTABILITY	Wheel Dolly Extra	Stationary	Stationary	Stationary	Casters
UNITS IN SERVICE	Begin in Fall 90	None	1st Ship Fall 90	None	Not Provided In Production for 3 Yrs
COST (PER UNIT)	$1995	$9000	$10,000	$11,000	$4345
AVAILABILITY	In Production	4th Quarter 90	Now	4th Quarter 90	In Stock

TABLE C-1. CFC RECOVERY/RECYCLING/RECLAMATION EQUIPMENT (CONTINUED).

COMPANY	VAN STEENBURGH ENGINEERING LABORATORIES	VAN STEENBURGH ENGINEERING LABORATORIES	WHITE INDUSTRIES DIVISION OF K-WHIT TOOLS, INC.	WYNN'S CLIMATE SYSTEMS, INC.	
MODEL	JV-90	BV-300	01060	90-0001A	
U.L. LISTED	No	No	Yes	No	
HALOCARBONS PROCESSED	12, 22, 500, 502	12, 22, 500, 502	12	12, 22, 502, 134a	
PROCESS PERFORMED	Recovery, Recycle	Recovery, Recycle	Recovery, Recycle	Recovery, Recycle	
METHOD OF PURIFYING	Filter, Velocity Gradient Separator	Filter, Velocity Gradient Separator	Filter, Velocity Gradient Separator	Filter/Drier Oil Separator	
CONTAMINANTS REMOVED	Particulates, Acids, Oils, Moisture	Particulates, Acids, Oils, Moisture	Particulates, Acids, Oils, Moisture	Particulates, Acids, Oils, Moisture	
INDICATION OF PURITY LEVEL	Moisture Sight Glass	Moisture Sight Glass	Moisture Sight Glass	Moisture Sight Glass	
RECOVERY RATE (LB/MIN)	5	5	0.5	1 to 2 Recovery, 2.5 Recycling	
PHYSICAL SIZE (W*D*H, IN)	28*24*60	42*24*60	13*13*45	20*19*41	
INTERNAL STORAGE CAPACITY (LB)	90	300	None	30	
WEIGHT (LBS)	325	750	115	150	
PORTABILITY	Casters	Casters	Casters	4 Casters	
UNITS IN SERVICE	Not Provided In Production for 3 Years	Not Provided In Production for 3 Years	7000	Approx. 50	
COST (PER UNIT)	$5445	$8100	$3492	$3250	
AVAILABILITY	In Stock	In Stock	6 Mo. Back Order	In Stock	

TABLE C-1. CFC RECOVERY/RECYCLING/RECLAMATION EQUIPMENT (CONCLUDED).

FOOTNOTES:

[a] N/A - Characteristic not applicable to the particular piece of equipment.

[b] Mailable liquid sample and analysis service available. Mailable sample container requires minumum of 15 grams (1/2 oz) of CFC and rents for $40. The sample analysis cost is $150 per NMR scan. Usually one hydrogen scan is adequate.

[c] The MDI PINNACLE Model 1000 A - B is a two-piece unit to improve portability. The "A" unit contains filtration section. The "B" unit contains the vapor compressor and condenser and can be used alone for recovery.

[d] Production Control Units, Inc., recovery/recycling units are built primarily for factory production lines for recovering CFCs from units requiring rework. Two of the smaller units are included in the table.

[c] Have not been UL certified but do have third party laboratory certification that SAE J 1991 purity requirements are met.

[f] The RTI units are engineered by the Danish firm A' Gramkow A/S, which has supplied units in Europe for over 10 years. These units are manufactured in the U.S. by RTI.

[g] This self-cleaning filter feature on the RRC 1000 and RREC 3000 models eliminates frequent filter changes according to RTI.

[h] Robinair is in high volume production and shipping models daily. In addition to those shown, they have shipped over 50% of a 10, producing others for Kent-Moore Tools, Inc. An additional 3700 units of the earlier model #17200 are in service.

[i] SERV-I-QUIP reclaimers are designed primarily for factory production line use.

TABLE C-2. HALON RECOVERY/RECYCLING/RECLAMATION EQUIPMENT.

COMPANY	APPLIED ECOLOGICAL SYSTEMS	APPLIED ECOLOGICAL SYSTEMS	CERBERUS PYROTRONICS	DAVCO	FRICK CO.
MODEL	R-2.2	R-2.4	Prototype for Internal Use Only	DM-275	VRU 10003
HALOCARBONS PROCESSED	1301	1301	1301	1301	1301
PROCESS PERFORMED	Recovery, Recycle	Recovery, Recycle	Recovery	Recovery, Liquid Only	Recovery Only
METHOD OF PURIFYING	Filters, Oil Traps	Filters, Oil Traps	None	N/A	N/A
CONTAMINANTS REMOVED	Particulates, Oil, Acids, Moisture	Particulates, Oil, Acids, Moisture	None	N/A	N/A
INDICATION OF PURITY LEVEL	Sight Glass Indicates Filter Needs Change	Sight Glass Indicates Filter Needs Change	None	N/A	N/A
RECOVERY RATE (LB/MIN)	1.5	2.5		30	1.5
PHYSICAL SIZE (W*D*H, IN)	12*21*12	13*24*12		12*28*11	30*22*15
INTERNAL STORAGE CAPACITY (LB)	8	12		None	None
WEIGHT (LBS)	54	60		95	185
PORTABILITY	Handle	Handle		2 Handles	
UNITS IN SERVICE	Approx. 350 Since 1980	Approx. 350 Since 1980		12 (Over Last 7 Years)	Hundreds
COST	$1115	$1316		$6499	$1800
AVAILABILITY	6 to 8 Weeks	6 to 8 Weeks		Stock to 60 Days	5 to 6 Weeks

TABLE C-2. HALON RECOVERY/RECYCLING/RECLAMATION EQUIPMENT.

COMPANY	GETZ	GETZ [a]
MODEL	HP 891301	HR-1
HALOCARBONS PROCESSED	1301	1211
PROCESS PERFORMED	Recovery Only Liquid Halon Pump	Recovery, Recycle Liquid, Vapor
METHOD OF PURFYING	N/A	Filter/Drier Charcoal
CONTAMINANTS REMOVED	N/A	Particulates, Moisture, Acids
INDICATION OF PURITY LEVEL	N/A	Moisture Sight Glass
RECOVERY RATE (LB/MIN)	27	50
PHYSICAL SIZE (W*D*H, IN)	28*20*34	20*26*39
INTERNAL STORAGE CAPACITY (LB)	N/A	150
WEIGHT (LBS)	200	250 w/Optional Compressor
PORTABILITY	2 Handles 4 Casters	Tubular Frame Casters Optional
UNITS IN SERVICE	5	Production Just Started
COST	$3900	$2995
AVAILABILITY	In Stock	In Stock

Notes:

[a] The U.S. Navy has procured and tested 12 prototype units from Getz Manufacturing, which is a now a subsidiary of Amerex Corp.

U.L. is currently developing a specification for Halon 1211 systems (UL 2006). It will not cover Halon 1301 systems.

TABLE C-3. CFC RECOVERY/RECYCLING/RECLAMATION SERVICES.

COMPANY	SERVICES
APPLIANCE RECYCLING CENTERS OF AMERICA	• SALVAGE AND RECYCLING OF HOUSEHOLD APPLIANCES WHICH INCLUDES REFRIGERATORS, FREEZERS, AND AIR-CONDITIONERS. • RECOVERS CFC-12 AND HCFC-22 AND RECYCLES FOR REUSE IN REPAIRED APPLIANCES. • CURRENT LOCATIONS ARE ST. PAUL, MN; MILWAUKEE, WI; AND JACKSONVILLE, FL.
DAVCO	• PROVIDES BULK CONTAINERS • RECLAIMS CFCs AT PLANT, (INITIALLY CFC-12, OTHERS LATER). • DOES NMR SPECTROMETER ANALYSIS • CERTIFIES PURITY
DUPONT CO.	• ACCEPTS RECOVERED CFCs -11, -12, -22, -113, -114, -500, AND -502 THROUGH AUTHORIZED DISTRIBUTOR NETWORK IN LOTS OF 500 LBS OR MORE. • REBATES OF UP TO $0.60/LBS AVAILABLE EXCEPT FOR HCFC-22. REBATE BASED ON QUALITY OF PRODUCT. AFTER PRODUCT QUALITY AND QUANTITY ARE VERIFIED, DUPONT PAYS FOR FREIGHT CHARGES. • CONTAINERS ARE AVAILABLE FOR A DEPOSIT.
INDUSTRIAL CHILLER SERVICES	• BUILT LARGE UNIT(3000 LBS) FOR ON-SITE RECOVERY/RECYCLE OF CFCs -11, -12, -22, -114, -500, -502 FROM LARGE REFRIGERATION/CHILLER UNITS • UNIT NOT FOR SALE • PERFORMS SERVICE FOR FEE • TESTED FOR PURITY ON REQUEST FROM CUSTOMER

TABLE C-3. CFC RECOVERY/RECYCLING/RECLAMATION SERVICES (CONCLUDED).

COMPANY	SERVICES
GREAT LAKES CHEMICAL CORP.	• ACCEPTS RECOVERED HALONS THROUGH AUTHORIZED DISTRIBUTOR NETWORK. • RECLAIMS THE HALONS AT THEIR PLANT.
NATIONAL REFRIGERANTS, INC.	• PROVIDES CONTAINERS AND RECOVERY UNITS • RECLAIMS CFCs -11, -12, -113, -114, -500, -502, AT PLANT • CERTIFIES PURITY
OMEGA RECOVERY SERVICES	• PROVIDES CONTAINERS FOR RECOVERED CFCs -11, -12, -113, -114, -115, -500, -502, -503 • RECLAIMS AT PLANT FOR FEES • CERTIFIES PURITY • PROVIDES DISPOSAL SERVICE FOR UNRECLAIMABLE CFCs

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